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THE MAMMALIAN VENA CAVA POSTERIOR

AN ONTOGENETIC INTERPRETATION OF THE ATYPICAL FORMS OF VENA CAVA POSTERIOR (INFERIOR) FOUND IN THE ADULT DOMESTIC CAT (FELIS DOMESTICA) AND IN MAN

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[1] Deceased, January 5, 1927.

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CHARLES F. W. McCLURE
Princeton University

AND

GEORGE SUMNER HUNTINGTON[1]
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FORTY-SIX PLATES (SIXTY-THREE FIGURES)

The material presented in this Memoir by Professor Charles F. W. McClure is the result of the joint investigation of Professors Huntington and McClure prior to 1920.

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[1] Deceased, January 5, 1927.

MEMOIR 15

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I. FOREWORD

The atypical condition of the vena cava posterior (inferior) often found in adult man and other mammals has for several decades been a matter of much interest to anatomists, and on this subject there has sprung up an extensive literature. In the late nineties, I began a study of this problem; and in 1905, Doctor Huntington became associated with me in a detailed investigation of the subject. The cases described in the literature before this time, as well as those which Doctor Huntington and I had separately observed, presented a wide range of atypical forms which neither of us could satisfactorily explain. It now appeared to us that since an atypical condition in the vena cava of an adult signifies a deviation in development from the typical plan, its ontogenetic interpretation would be found in the detailed study of the development of all embryonic vessels which had entered into the formation of the venous system. Accordingly, we set about making a joint investigation of the development of veins in the cat, as most of the atypical conditions observed by us were to be found in the variants of this animal. During the course of our work we became involved in the problem of the genesis of the lymphatics, and in consequence the publication of our joint paper on the development of the veins in the cat was delayed until 1920. It is largely due to Doctor Huntington's prolonged illness, dating from about 1918, and his death in 1927, that the publication of this memoir has been delayed to the present time.

The basic material presented in this memoir is the result of our joint work, accomplished before Doctor Huntington's illness. Our purpose has been to illustrate and to interpret from the standpoint of their development all known atypical forms of vena cava posterior. We have constructed a composite ontogenetic diagram of the embryonic venous system, on the basis of which we have classified under seventeen main

Types the atypical or variant conditions of the vena cava, actual as well as potential, in the adult cat. Furthermore, not only have we interpreted all the atypical forms of the cava already known, but also we have predicted the existence of others, some of which, since the publication of our first papers, actually have been reported by other investigators as found in the adult cat and in man.

In the following pages I have presented the results of our investigation in its original intention. While in recent years I have been without the advice and wise counsel of my colleague, I trust, nevertheless, that I have been able to do full justice to our subject, and that I have carried to a successful conclusion the work projected in 1905, continued by us jointly through fifteen happy years, and brought to date and finished by me since Doctor Huntington's illness and death.

Charles F. W. McClure.

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II. THE NORMAL AND THE ATYPICAL VENA CAVA POSTERIOR (INFERIOR)

The explanation and interpretation of the atypical conditions of the vena cava posterior encountered by us in an extensive series of adult examples of Felis domestica are fully to be found in the comprehensive system of embryonic venous channels normally functioning in different ontogenetic stages. The acquisition of what is regarded as the normal type of vena cava in the cat is contingent on the selection and the continued development in the majority of individuals of certain venous pathways into the adult stage. The average individual thus assumes the venous type considered normal for the species. Any deviation from this plan is to be regarded as an atypical condition or variant. It is brought about by the selection and continued development of other existing embryonic channels which normally are not carried into the adult stage.

The vena cava posterior in any one of its atypical forms has usually been described by anatomists as an 'abnormality.' In the sense that an atypical condition is not normally encountered in the adult, such a designation is correct. On the other hand, all atypical cavae mentioned in the following pages are normal rather than pathological, in the sense that they are derived from vessels which during the course of ontogenetic development have normally functioned in the embryo.

III. THE SUPRACARDINAL SYSTEM OF VEINS

In 1905, when we first began a comprehensive study of the development of veins in the cat, it was generally supposed that the posterior cardinal vein of the embryo entered directly into the formation of the lumbar portion of the vena cava posterior. The acceptance of this view was due to the brilliant pioneer work of Hochstetter ('93), whose figures illustrating the development of the veins are well known to all anatomists. While we recognize the importance of Hochstetter's investigations, they are nevertheless lacking in details sufficient to explain all atypical conditions observed in the adult mammal, especially in the cat. What we found to be the case is that the posterior cardinal vein, as such, does not, as has hitherto been supposed, enter into the formation of the cava in the lumbar region of the cat. The dorsal limb of the periureteric venous ring from which, according to Hochstetter, the lumbar cava also is in part formed, does not split off from the posterior cardinal, but belongs to a separate and independent system of veins which we have designated the *supracardinal system of veins.*

In 1907,[2] we described the supracardinal system of veins as follows:

> A bilateral and originally symmetrical venous channel develops dorsomedial to the primitive postcardinal vein by longitudinal anastomoses between somatic postcardinal tributaries. This secondary vein channel forms what we have termed the *supracardinal system of veins.* It extends from the level at which the posterior limb veins open into the postcardinals to a point cephalad where it joins that portion of the postcardinals which alone persists to form the anterior end of the adult azygos. Between these levels the supracardinal enters into the definite organization both of the adult postcava in its postrenal division and of the azygos in its lumbar and part of its thoracic segments, entirely replacing in these districts the primitive postcardinal veins. The postrenal division of the adult postcava is formed as the result of a secondary median fusion by means of transverse anastomoses dorsal to the aorta of the postcaval portions of the supracardinals, the primitive postcardinal veins not entering into the formation of this portion of the main trunk of the adult vessel.

IV. A RECONSTRUCTION OF THE AXIAL VEINS IN THE LUMBAR REGION OF A 16-MM. CAT EMBRYO

It is not the purpose at the present time to describe again, in detail, the development of veins in the cat. This we have already done in a paper published in 1920, to which the reader is referred.[3] The chief object which the present publication has in view is to bring together all atypical forms of the

[2] Am. Jour. Anat., vol. 6 (Proc. Ass. Amer. Anat.).

[3] Anat. Rec., vol. 20.

vena cava posterior which have been observed by us and by others, especially in adult man[4] and the cat, and to show how they may be interpreted as modifications of a normal ontogenetic venous plan. Such a composite ontogenetic plan of the veins is shown in figure 1. Here are represented the main axial venous channels and their anastomoses, which, in the cat, make their appearance at one time or another during the course of ontogeny. Under normal conditions certain of these veins function only temporarily and then disappear, while others are carried into the adult stage. Atypical conditions of the veins are brought about by the persistence of some one or more of the embryonic channels which normally are not carried into the adult stage.

Before considering the composite ontogenetic plan of the veins as depicted in figure 1, we will examine a typical reconstruction of the veins of the cat, the basis upon which in general the composite diagram (fig. 1) is built. Such a reconstruction is represented in figures 2 and 3, which show the main axial venous channels in the lumbar region on the right (fig. 2) and the left (fig. 3) sides of a 16-mm. cat embryo. These axial vessels consist of the right and the left supracardinals (*Sprc.*, *B* and *C*) and the right and the left posterior cardinal veins (*Pc.*, *A* and *D*). At an earlier stage of development both supracardinal and posterior cardinal veins extended as continuous vessels throughout the lumbar and the thoracic regions, so that blood from the caudal region of the body could pass directly to the heart through either the supracardinal or the posterior cardinal veins. The separation of these vessels into a lumbar and a thoracic division has been brought about by the formation of the unpaired prerenal division of the vena cava (*P.Hep.*, *P.Sub.*, and *Int.Subc.Anast.*), through which, in the 16-mm. embryo, all blood collected by the lumbar axial veins is now returned to the heart. The prerenal division of the vena cava is joined by the axial veins of the lumbar region at about the level at which the embryonic renal veins (*R.V.*) are found. In this region, by extensive anastomoses, the veins almost completely encircle the aorta, forming a circumaortic venous ring, which we have designated the *renal collar.* In order to reach the prerenal division of the vena cava, blood in the lumbar supracardinals must pass, on each side of the body, through the lateral portion of the renal collar (*Subc.Sprc.Anast.*), and blood from the posterior cardinals (*Pc., A* and *D*), which drain the gonads and the mesonephroi, reaches the prerenal division of the cava through the subcardino-posterior cardinal anastomosis (*Subc. Pc.Anast.*) without passing through the lateral portion of the renal collar.

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[4] The publication by McClure and Butler, in 1925, on the development of the vena cava inferior in man, has made it possible for the writer to confirm and to enlarge upon our previous observations.

On the right side of the embryo (fig. 2), a complete periureteric venous ring is present, through which the ureter (*Ur.*) passes. The ventral circumference of this ring is formed by the right lumbar posterior cardinal (*Pc.Dext., A*), and its dorsal circumference by the right lumbar supracardinal vein (*Sprc.Dext., B*). On emerging from the kidney, the ureter at first passes dorsal, and farther caudad, ventral to the posterior cardinal, lying between the aorta and this vein. On the left side of the embryo (fig. 3), no periureteric venous ring is present. Its absence is due to the loss of a caudal connection which previously existed between the left lumbar supracardinal (*Sprc.Sin., C*) and the left lumbar posterior cardinal vein (*Pc.Sin., D*). The relations which the ureter bears to the posterior cardinal and the supracardinal veins remain the same, however, on the left as on the right side.

The posterior cardinal veins join the renal collar at its ventrocaudal border and collect blood from the mesonephroi and the sex glands (gonads). With the disappearance of the mesonephroi, the posterior cardinal veins retain their connection with the gonads through the subcardinal veins and, together with the subcardinals, form the internal spermatic veins of the adult.

It is evident, for the most part, that in the 16-mm. cat embryo the veins of the lumbar region still retain their early bilaterally symmetrical plan—a condition which later becomes transformed into an asymmetrical one. This change is brought about chiefly by the loss and atrophy of vessels on the left side. For example, the vena cava posterior of the adult cat is derived from the following embryonic veins: the right lumbar supracardinal (*Sprc.Dext., B*), which retains, through a dorsal anastomosis, a connection with the left iliac vein; the right subcardino-supracardinal anastomosis (*Subc.Sprc. Anast.*, the right side of the renal collar); the right subcardino-posterior cardinal anastomosis (*Subc.Pc.Anast.*); the intersubcardinal anastomosis (*Int.Subc.Anast.*); a portion of the right subcardinal, the pars subcardinalis (*P.Subc.*), and the V. hepatica communis and the hepatic sinusoids (pars hepatica, *P.Hep.*). The lateral portion of the renal collar on the left side and the cranial half, at least, of the left lumbar supracardinal (fig. 3) undergo atrophy; but the caudal half of the left lumbar supracardinal appears to fuse with the right to form the caudal half of the adult caval vein.

With the atrophy of the left side of the renal collar (*Subc. Sprc.Anast.*, fig. 3), the left renal vein (*R.V.*) retains its connection with the left subcardino-posterior cardinal anastomosis (*Subc.Pc.Anast.*), which forms the proximal portion of the adult left renal vein. Into the latter the left posterior cardinal (*Pc.Sin., D,* fig. 3), with its gonad tributaries, opens, thereby establishing the adult condition in which the internal spermatic vein joins the left renal vein. On the right side of the embryo (fig. 2), the right embryonic renal vein (*R.V.*) retains its original connection with the right side of the renal collar (*Subc.Sprc.Anast.*), which forms a segment of the adult caval vein. The right posterior cardinal (*Pc.Dext., A*), with its gonad tributaries, also retains its connection with the renal collar at its ventrocaudal border, and owing to an elongation, in a craniocaudal direction, of the right side of the collar (*Subc.Sprc.Anast.*), the junction of the posterior cardinal with the cava is carried somewhat caudal to that of the right renal vein. In this manner we can account for the difference which exists on opposite sides of the body, in the junction of the internal spermatic vein with the cava.

V. THE COMPOSITE ONTOGENETIC VENOUS PLAN OF THE CAT

We may now pass to a consideration of the composite ontogenetic plan of the veins (fig. 1). In this diagram are shown two important sets of vessels not represented in the reconstruction of the veins in the 16-mm. cat. These are the subcardinal and the cardinal collateral veins. In the 7- to 8-mm. cat embryo the subcardinals form a bilaterally symmetrical system of veins, which anastomose with the posterior cardinal veins and, ventral to the aorta, with each other. They receive blood from the mesonephroi and the sex glands. The cardinal collateral veins, which are not shown in their entirety in the diagram, reach the height of their development at approximately the 29-mm. stage, and for this reason were not evident in the 16-mm. cat. It is also to be noted that, except for its cranial end, the thoracic division of the posterior cardinal veins has not been shown in the diagram (fig. 1).

If we compare figure 1 with figures 2 and 3, we shall see that in none of its fundamental aspects does the composite plan of the embryonic veins exaggerate the condition actually observed.

If we examine the composite ontogenetic venous plan of the cat (fig. 1), we observe that three pairs of longitudinal bilaterally symmetrical venous channels are represented in the lumbar region and that they consist of the posterior cardinals (*A* and *D*), the supracardinals (*B* and *C*), and the subcardinals (*Subc.*) into which the sex veins (Vv. spermaticae, *S.V.*) open. It is to be observed that the supracardinals anastomose with the posterior cardinals (*Pc.Sprc.Anast.*) and, *dorsal* to the aorta, with each other (*Int.Sprc.Anast.*); and that the subcardinals anastomose with the posterior cardinals (*Subc.Pc.Anast.*) and, *ventral* to the aorta, with each other (*Int.Subc.Anast.*). In addition to the three pairs of longitudinal vessels, there is shown at the iliac level a median vein (*C.C.*) lying *ventral* to the aorta which, with contiguous veins, forms venous rings through which pass the umbilical arteries. This has been termed the cardinal collateral vein (*C.C.,* fig. 1), as it is a caudal component of a longitudinal subaortic system of veins, between the iliac and the renal levels, which, though transitory in the cat, in marsupials forms the vena cava posterior (McClure, '06). This subaortic plexus (*C.C.,* cardinal collateral system of veins) reaches the height of its development in the lumbar region of a 29-mm. cat embryo, as is shown in figures 4 and 5, representing, respectively, the right and the left sides of a reconstruction.

The veins at the renal level form a prominent circumaortic venous ring, which we have designated the renal collar (fig. 1). It is in this region that all the early bilaterally symmetrical longitudinal venous channels drain into the unpaired prerenal division of the posterior vena cava (*P.Subc.* and *P.Hep.*) which, from the renal collar, extends craniad through the liver to the right auricle.

The bilaterally symmetrical periureteric venous rings of early stages, through which pass the ureters, are accurately represented in the diagram (fig. 1). It is to be observed that as each ureter (*Ur.*) emerges from the kidney, it at first passes *dorsal* and then farther caudad *ventral,* to the posterior cardinal vein.

The supracardinal system of veins (*Sprc.*) is shown in the diagram (fig. 1) as a bilaterally symmetrical system of veins, extending as continuous vessels through the lumbar and the thoracic regions. In the thoracic, as in the lumbar region, the supracardinals anastomose freely with each other *dorsal* to the aorta, and it is from this intersupracardinal complex (*Int.Sprc.Anast.*) that the dorsally situated azygos vein of the adult is for the most part developed.

If the reader will take the trouble to master the simple conditions represented in figure 1, existing amongst the longitudinal venous channels and the anastomoses between them at different levels, he will have no difficulty in interpreting

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the variant conditions presented by the veins in the adult cat or in man, to be described in the following pages.

As longitudinal channels, the subcardinals in the cat lose their identity at a relatively early stage of development, and the chance of their being retained in the adult in their embryonic form is negligible. With the exception of the intersubcardinal anastomosis at the renal level (*Int.Subc.Anast.*, fig. 1), of the pars subcardinalis of the vena cava (*P.Subc.*), of a segment of the internal spermatic veins, and of the adrenal veins, the subcardinals are not otherwise carried into the adult stage.

The subaortic plexus in the lumbar region (cardinal collateral veins, *C.C.*, in figs. 4 and 5) develops late in ontogeny, in connection with the supracardinals, after the latter have assumed the function of returning practically all blood from the iliac veins to the prerenal division of the cava; therefore, the chance of these veins being retained in the adult is likewise very slight. The posterior cardinals, however (*A* and *D*, fig. 1), function as important vessels in conveying blood from the iliac region to the prerenal division of the cava until a relatively late stage of development (16- to 17-mm. cat embryo), and then are gradually replaced in performing this function by the supracardinal veins (*B* and *C*, in fig. 1). The persistence of the two posterior cardinals and the two supracardinals so late in ontogeny as conveyors of blood from the iliac veins to the prerenal division of the cava, accounts for the fact that some one, or else a combination of two or more of them, is often carried into the adult to establish an atypical condition. Most of the atypical forms of cava found in the lumbar region of the adult cat are due to the persistence of the right posterior cardinal, of the left supracardinal, of the left posterior cardinal, or of any one of the possible combinations which exist between the two posterior cardinal and the two supracardinal veins. As a matter of fact, there are in the lumbar region fifteen (15) possibilities of the persistence of one or more of these four veins. One of them constitutes the normal type of cava, while fourteen are atypical in character.

These *Types* are as follows (see *A, B, C,* and *D,* in fig. 1):

1. *Type A,* persistence of right posterior cardinal vein (*A*).

2. *Type AB,* persistence of right posterior cardinal (*A*) and right supracardinal (*B*) veins. Right periureteric venous ring present, through which ureter passes.

3. *Type ABC,* persistence of right posterior cardinal (*A*), right supracardinal (*B*), and left supracardinal (*C*) veins. Right periureteric venous ring present, through which ureter passes.

4. *Type ABCD,* persistence of right posterior cardinal (*A*), right supracardinal (*B*), left supracardinal (*C*), and left posterior cardinal veins (*D*). Right and left periureteric venous rings present, through which ureters pass.

5. *Type ABD,* persistence of right posterior cardinal (*A*), right supracardinal (*B*), and left posterior cardinal veins (*D*). Right periureteric venous ring present, through which ureter passes.

6. *Type AC,* persistence of right posterior cardinal (*A*), and left supracardinal veins (*C*).

7. *Type ACD,* persistence of right posterior cardinal (*A*), left supracardinal (*C*), and left posterior cardinal veins (*D*). Left periureteric venous ring present, through which ureter passes.

8. *Type AD,* persistence of right (*A*) and left (*D*) posterior cardinal veins.

9. *Type B,* persistence of right supracardinal vein (*B*) to form the lumbar division of the posterior vena cava. *Normal cava.*

10. *Type BC,* persistence of right (*B*) and left (*C*) supracardinal veins.

11. *Type BCD,* persistence of right (*B*) and left supracardinal (*C*), and left posterior cardinal veins (*D*). Left periureteric venous ring present, through which ureter passes.

12. *Type BD,* persistence of right supracardinal (*B*) and left posterior cardinal veins (*D*).

13. *Type C,* persistence of left supracardinal vein (*C*).

14. *Type CD,* persistence of left supracardinal (*C*) and left posterior cardinal veins (*D*). Left periureteric venous ring present, through which ureter passes.

15. *Type D,* persistence of left posterior cardinal vein (*D*).

With the exception of *Types* ABD, ABCD, BCD, and CD, all the atypical forms above mentioned have been observed in adult man or the cat either by us or by others. *Type* ABCD, however, has been figured by Hochstetter ('93) as occurring in Erinaceus europaeus.

There are three additional types in which the vena cava posterior may appear in the adult cat and in man in atypical form:

16. Persistence of embryonic supracardinal system of veins to form a continuous system of vessels in the lumbar and the thoracic regions, by means of which blood from the iliac region can be conveyed directly to the heart, without passing through the liver.

17. Persistence of renal collar (circumaortic venous ring at level of renal veins).

18. Persistence of subaortic plexus or cardinal collateral veins (*C.C.* in fig. 1). *Marsupial Type* of vena cava posterior.

Although for convenience of description we have classified the potential variant or atypical conditions of the vena cava posterior into the above-mentioned individual types, we recognize that in the same individual a combination of several types does occasionally occur. Such a classification, based upon a comprehensive ontogenetic plan of the veins, is a distinct advance over our former knowledge; it not only permits us to interpret the atypical forms of cava thus far observed, but also enables us to predict others which are potential and remain still to be found.

VI. THE ATYPICAL FORMS OF THE VENA CAVA POSTERIOR IN ADULT MAN AND THE CAT, INTERPRETED ON THE BASIS OF THEIR DEVELOPMENT FROM A COMMON GROUND PLAN, BY THE SELECTION OF POTENTIALLY AVAILABLE PATHWAYS IN THE EMBRYO

In the following pages there are given examples of atypical forms of the vena cava posterior thus far observed in both man and the cat. These atypical conditions can be interpreted on the basis of their development from a common ground plan, through the selection of potentially available venous pathways in the embryo. The variants described for man have been drawn from the anatomical literature dealing with this topic and from the extensive Huntington Collection in the College of Physicians and Surgeons of Columbia University. The adult material of the cat was in large part prepared by Professor William Darrach, in connection with the courses in mammalian anatomy in Columbia University. He examined 605 adult cats, and at the Twenty-first Annual Meeting of the American Association of Anatomists (December, 1906), reported the variations of the vena cava posterior and its tributaries, as shown by this series. His report is published in the Proceedings of the Association, Anatomical Record, no. 3, 1907. We wish here to express our deep obligations to Professor Darrach for his painstaking work, done largely in our behalf. Since the work of Professor Darrach, further extensive observations have been made by the writers in the Departments of Comparative Anatomy of Princeton and Columbia Universities.

As we have shown elsewhere, certain of these embryonic venous pathways which are not retained in the adult undergo atrophy, and the position formerly held by them is assumed by a lymphatic. This process has been termed by us the ''extra-intimal replacement of a vein by a lymphatic.'' For a more complete understanding of the process involved, the reader is referred to our joint paper published in 1907,[5] in which this view was first advanced, and to papers published by us separately in 1910.

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[5] Am. Jour. Anat., vol. 6 (Proc. Ass. Amer. Anat.).

We may now proceed to a detailed consideration of the atypical conditions of the vena cava posterior as found in the adult cat and in man.

1. *Persistence of right posterior cardinal vein*

Type A (*A* in fig. 1). Figures 6 and 7, cat (Darrach Series), and figure 8, man (Gladstone, '12)

A single main axial vein, to the right of the aorta, manifests itself as the persistent right posterior cardinal vein (vena cava posterior) by its relation to the right ureter, which lies at first dorsal to the vein, emerges between the latter and the right side of the aorta, and descends caudolateral over the ventral surface of the cava.

As shown in the reconstruction (fig. 2) and in the composite diagram (fig. 1), the right side of the renal collar (*Subc.Sprc.Anast.*) does not enter into the formation of the lumbar cava when in the adult the posterior cardinal vein (*A*) alone persists to form the cava. A vena cava posterior of *Type* A develops along the following pathways in figure 1: pars hepatica (*P.Hep*), pars subcardinalis (*P.Subc.*), intersubcardinal anastomosis (*Int.Subc.Anast.*), subcardino-posterior cardinal anastomosis (*Subc.Pc.Anast.*) and right posterior cardinal vein (*A*). In the examples of *Type* A represented by figures 6, 7, and 8, the iliac veins of the left side have established their connection with the cava (*A,* fig. 1) by the persistence of an anastomosis, dorsal to the aorta, between the main axial veins of opposite sides.

In figures 6, 7, and 8, the sex vein on the right side opens into the right posterior cardinal (cava) and on the left side, into the left renal vein. The anastomosis between the sex veins of opposite sides in figure 6 is due to the persistence of an embryonic intersubcardinal anastomosis (*Int.Subc.Anast.,* fig. 1), ventral to aorta, somewhat caudal to the renal level. Darrach observed this anastomosis in only two cases of his series of 605 adult cats. In *Type* A of the cat, the right sex vein (*V. spermatica*) is derived from the subcardinal plexus (*S.V.,* fig. 1) of the right sex gland, together with one (fig. 6) or more (fig. 7) of the subcardino-posterior cardinal anastomoses (*Subc.Pc.Anast.,* fig. 1) caudal to the renal level, between the right subcardinal (*Subc.*) and the right posterior cardinal veins (*A,* fig. 1). The left sex vein of the cat is formed by the subcardinal plexus of the left sex gland (*S.V.*), by a left subcardino-posterior cardinal anastomosis (*Subc.Pc. Anast.Sin.,* fig. 1), and by a segment of the left posterior cardinal vein (*D,* fig. 1). At the renal level the latter joins the left subcardino-posterior cardinal anastomosis (*Subc.Pc. Anast.*) which, after atrophy of the left side of the renal collar (*Subc.Sprc.Anast.Sin.*), becomes the proximal portion of the left renal vein of the adult. Figure 5, which represents a stage of development in which the left side of the renal collar has completely disappeared (*Subc.Sprc.Anast.*), makes plain the composition and the relations of the left sex vein in the adult cat. Figure 5 should be compared with figure 3, in which is present the left side of the renal collar.

Type A was found by Darrach in twenty-two, or 3.6 per cent, of the 605 adults examined. It has been figured as occurring in the cat by Hochstetter ('93) and Gage ('98); in the cat and the rabbit by Graves and Davidoff ('22); and in man by Hochstetter ('93), Huntington ('07), Kolisko ('09), and Gladstone ('11).

2. *Persistence of right posterior cardinal and right supracardinal veins. Right periureteric venous ring present, through which ureter passes*

Type AB (*A* and *B* in fig. 1). Figures 9 and 10, cat (Darrach Series)

This interesting variant (figs. 9 and 10) shows a condition in which the right ureter passes through a periureteric venous ring. The dorsal circumference of this venous ring is formed by the right supracardinal vein; its ventral circumference, which receives the right sex vein, is formed by the right posterior cardinal. As shown in the composite diagram (fig. 1), the periureteric venous ring is due to the persistence of A and B; the common trunk cranial to the venous ring, between the ring and the renal veins (*R.V.*), has resulted from an elongation of the right side of the renal collar (*Subc. Sprc.Anast.*). The changes brought about by this elongation can easily be seen in those figures in our joint paper which illustrate the development of the renal collar (Huntington and McClure, '20, figs. 8, 9, 10, and 11). Especially in figure 11 (H. and McC.) is clearly demonstrated the relation that exists between the elongated renal collar and the right sex vein (posterior cardinal).

An examination of a number of examples of *Type* AB in the cat has shown that the caudal extent of the periureteric venous ring varies in individual cases, extending caudad, as in figure 9, to the iliolumbar veins or, as in figure 10, only to a point somewhat craniad of this level. Differences in the caudal extent of the venous ring are dependent upon the extent to which either the right posterior cardinal or the right lumbar supracardinal vein may be involved in the ring's formation. When practically the entire right lumbar supracardinal vein persists, the venous ring extends caudad to the iliolumbar level (fig. 9). When only a portion of the right lumbar supracardinal vein persists, the caudal extent of the ring is determined by the level at which, cranial to the iliolumbar level, an anastomosis (*Pc.Sprc.Anast.*, fig. 1) is retained between the right posterior cardinal and the right supracardinal veins.

Type AB was found by Darrach in only three, or 0.5 per cent, of the adult cats examined. It was described for the cat by Gage in 1898; but, so far as we know, has been observed in man only by Wicke ('27)[6] and possibly by Melissinos in a doubtful case figured by him in 1911.

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[6] This case described by Wicke is a most unusual one. In addition to the presence of a right periureteric venous ring (*Type* AB), the left common iliac vein passes ventral, instead of dorsal, to the right common iliac artery, indicating the persistence of a channel derived from the cardinal collateral vein (*C.C.* in fig. 1). See figure 63, plate XLVI.

3. Persistence of right posterior cardinal, right supracardinal, and left supracardinal veins. Right periureteric venous ring present, through which ureter passes

Type ABC (*A, B,* and *C* in fig. 1). Figure 11, cat (Darrach Series)

Figure 11 shows a case in which the vena cava posterior is represented in the lumbar region by three para-aortic channels, which enclose a right and a left venous ring. On the right side the ureter passes through the ring, establishing a typical periureteric venous ring. On the left side, however, the ureter extends between the kidney and the bladder without passing through the left venous ring. The relations which the ureters bear to the venous rings clearly indicate that the veins which form the rings have been derived from the right posterior cardinal and the right and the left supracardinal veins. The left para-aortic channel (left supracardinal vein) joins the right supracardinal, *dorsal* to the aorta, at a level somewhat caudal to that of the renal veins. This indicates that only a caudal section of the left lumbar supracardinal is concerned, and that by means of an intersupracardinal anastomosis, at a low level, it has retained a connection with the right supracardinal vein (*Int.Sprc.Anast.*, fig. 1).

So far as we can determine, the example illustrated by figure 11 is the only instance in which *Type* ABC has been described in the adult cat or in any other mammal.

4. Persistence of right posterior cardinal, right supracardinal, left supracardinal, and left posterior cardinal veins. Right and left periureteric venous rings present, through which ureters pass

Type ABCD (*A, B, C,* and *D* in fig. 1)

So far as we are aware, no instance of *Type* ABCD has ever been described, either for the adult cat or for man. The only case we know in which this type has been found to occur in an adult mammal is that described by Hochstetter for Erinaceus europaeus ('93, Taf. XXIII, fig. 24). Since *Type* ABCD uniformly occurs as a transitory stage in the development of both cat and man, it is a potential condition present in the embryo, and, as a variant, might be carried into the adult stage.

5. *Persistence of right posterior cardinal, right supracardinal, and left posterior cardinal veins. Right periureteric venous ring present, through which ureter passes*

Type ABD (*A, B,* and *D* in fig. 1)

So far as we have determined, no example of *Type* ABD has thus far been observed, either in the adult cat or in any other mammal. As in the case of *Type* ABCD, *Type* ABD occurs as a transitory stage in the development of both cat and man and is therefore potential as a variant in the adult stage.

In this connection it is of interest to study a reconstruction of the veins in the lumbar region of a 21-mm. cat embryo. This reconstruction is instructive for the reason that it illustrates clearly the method by which venous transformations in the embryo lead to the formation of definite types of cavae.

On the right side of this embryo (fig. 12), there is present a periureteric venous ring, through which the ureter passes. The relation which the ureter bears to the ring clearly indicates that the veins which enclose the ring are the right posterior cardinal (*Pc., A*) and the right supracardinal veins (*Sprc., B*). On the left side of the embryo (fig. 13), the left posterior cardinal (*Pc., D*) has given up its connection with the supracardinal (*Sprc.*), *though only recently,* as is indicated, near the ureter (*Ur.*), by the narrow break in the left posterior cardinal vein (*Pc.*). We have here an instance in which *Type* ABD has recently been transformed into *Type* AB. Also, judging from the difference in size that exists between the right supracardinal (*Sprc.,* fig. 12) and the right posterior cardinal veins (*Pc.*), it seems probable, if development had proceeded further, that the right supracardinal (*Sprc.*) would have continued to atrophy and that the right posterior cardinal (*Pc.*) would alone have been retained in the adult to form a cava of *Type* A.

Another interesting feature of this embryo is the atrophied character of the left side of the renal collar (*Subc.Sprc. Anast.*, fig. 13), into which the left embryonic renal vein opens (*R.V.*). Ordinarily, the left side of the renal collar, with the left embryonic renal vein, breaks away from the supracardinal (*Sprc.*), and the left renal vein of the adult cat is thereby formed. The renal vein of the adult cat, formed in this manner by the left embryonic renal vein (*R.V.*), the left side of the renal collar (*Subc.Sprc.Anast.*), and the left subcardino-posterior cardinal anastomosis (*Subc.Pc.Anast.*, figs. 1 and 13), passes *ventral* to the aorta and receives the left sex vein (posterior cardinal and sex-vein tributaries) before joining the vena cava. However, if the left side of the renal collar with the embryonic renal vein (*R.V.*) should give up its connection with the subcardino-posterior cardinal anastomosis (*Subc.Pc.Anast.*) and retain its connection with the supracardinal vein (*Sprc.*), the left renal vein would then pass dorsal to the aorta before joining the caval vein. This latter condition is one not uncommonly found as a variant in the adult cat and in man, and is the normal condition found in the adult bat (Hochstetter, '93; Grosser, '01, and Butler, '27).

6. Persistence of right posterior cardinal and left supracardinal veins

Type AC (*A* and *C* in fig. 1). Figures 14, 15, and 16, cat (Darrach Series)

Of the two para-aortic axial veins shown in figures 14, 15, and 16, the vein of the right side is of posterior cardinal origin. This is evident from the relation which the right ureter bears to the vein. As in *Type* A (fig. 6), the right ureter on emerging from the kidney at first passes dorsal, and, farther caudad, ventral to the right cava.

The left para-aortic axial vein manifests considerable variation in the three examples shown. In one case (fig. 14) it extends only between the left iliac and the left iliolumbar veins, at which point it passes *dorsal* to the aorta to join the right caval vein (posterior cardinal). In another case (fig. 15) it forms a direct continuation of the left iliac vein and joins the right cava (posterior cardinal) *dorsal* to the aorta, at a point somewhat caudal to the level of the renal veins. In the third case (fig. 16) the left para-aortic axial vein extends as a continuous vessel between the left iliolumbar and the left renal veins, and at about its caudal third receives the left spermatic vein, which in figures 14 and 15 opens into the left renal vein. In all three cases mentioned, the left ureter extends from the kidney to the bladder, without passing between the aorta and the left para-aortic axial vein. One may therefore interpret the left para-aortic axial vein in figures 14, 15, and 16 as due to the persistence in part (figs. 14 and 15), or in whole (fig. 16), of the left lumbar embryonic supracardinal vein. In figure 14 the caudal fifth, in figure 15 the caudal two-thirds, and in figure 16 the entire embryonic lumbar supracardinal vein have been retained. The connection, *dorsal* to the aorta, which the left para-aortic axial vein makes with the right cava in figures 14 and 15 is due to the persistence of anastomoses which, at different levels, exist in early stages between the left supracardinal and the right posterior cardinal veins (*Int.Sprc.Anast.* and *Pc.Sprc.Anast.*, fig. 1).

Type AC in the cat was first described by Gage in 1898. It was found in only four of the 605 cats examined by Darrach. We know of no instance in which *Type* AC has been found in man.

7. Persistence of right posterior cardinal, left supracardinal, and left posterior cardinal veins. Left periureteric venous ring present, through which ureter passes

Type ACD (A, C, and D in fig. 1). Figure 17, cat (Metcalf, '18)

Figure 17 is a photograph of *Type* ACD, described and figured by Metcalf as occurring in an adult cat. So far as we could determine, this variant marks the only instance on record in which *Type* ACD has been either observed or described as occurring in the adult cat or in any other mammal. Also, with the exception of Erinaceus europaeus, described by Hochstetter ('93), the case figured by Metcalf is the only one on record in which a periureteric venous ring on the *left* side has been described as occurring in an adult mammal.

In the early stages of development a symmetrical arrangement of the main axial veins is a marked feature. One of the earliest changes which transposes the symmetrical embryonic plan to an asymmetrical one is the discontinuance of the left periureteric venous ring, through a break which occurs in the left posterior cardinal, near the point where the vein is crossed by the ureter (*Pc.* and *Ur.* in fig. 13). The early disappearance in ontogeny of the left periureteric venous ring undoubtedly accounts for the fact that this ring is rarely carried as a variant into the adult stage.

When compared with the composite ontogenetic plan of the veins (fig. 1), as typical an example of *Type* ACD as could exist is shown in figure 17. In the absence of an anastomosis, dorsal to the aorta, between the right and the left common iliac veins, all the blood from the right iliac veins is directed into the right posterior cardinal (right cava), about which the ureter winds. The right lumbar cava is composed only of the right posterior cardinal (*A*, fig. 1) and the right subcardino-posterior cardinal anastomosis (*Subc.Pc.Anast.*, fig. 1). The lateral portion of the renal collar (*Subc.Sprc.Anast.*) does not enter into the formation of the cava when the cava is formed by a posterior cardinal vein. A typical periureteric venous ring is present on the left side (fig. 17). The dorsal circumference of the ring is formed exclusively by the left supracardinal (*C* in figs. 1 and 17) and is of less importance functionally than the ventral circumference of the ring, which has been derived from the left posterior cardinal vein (*D* in fig. 1).

8. Persistence of right and left posterior cardinal veins

Type AD (A and D in fig. 1). Figures 18, 19, 20, 21, 22, 23, 24, cat (Darrach Series), and figure 25, man (Gladstone, '12)

Figures 18 to 24, inclusive, represent different variations of *Type* AD, in which two caval veins are present in the lumbar region, derived, respectively, from the right and the

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left embryonic posterior cardinal veins. Their posterior cardinal origin is plainly manifested by the typical relation which the ureters bear to the veins (fig. 2). In *Type* AD there enters into the formation of the caval veins neither the lateral portions of the renal collar (*Subc.Sprc.Anast. Dext.* and *Sin.,* fig. 1) nor the supracardinal veins (*B* and *C,* fig. 1). However, in addition to the posterior cardinals (*A* and *D,* fig. 1), the right and the left subcardino-posterior cardinal anastomoses (*Subc.Pc.Anast.,* fig. 1) have also been retained. In figure 18 the right and the left caval veins are about subequal in size, while in figure 19 the vein of the right side is functionally the more important. There is considerable variation in the iliac region, in the connections between the caval veins of opposite sides. In some cases, as in figure 20, no connection whatever is present between these veins; in figure 21 only a slight one exists, through a right and a left fork of the caudal vein. Cases of incomplete fusion, in which arteries pass dorsal through foramina in the caval veins, recall early conditions in the embryo (figs. 3, 4, and 5), and are shown in figures 22 and 23; cases in which the fusion is complete in the iliac region between the veins of opposite sides are shown in figures 18, 19, 22, 23, and 24.

When either one or both of the caval veins have a posterior cardinal origin, it is important to note that the internal spermatic or sex veins, either single (fig. 19) or multiple (fig. 18), join the cava (posterior cardinal) somewhat caudal to the renal level. With the loss of the distal segment of the left posterior cardinal (figs. 18 to 24, inclusive), it is evident that the left spermatic vein would then, as under normal conditions, open into the left renal vein, and that a considerable portion of the left spermatic vein would be formed by the left posterior cardinal. This clearly demonstrates that the left spermatic vein of the adult is derived in part from the subcardinal and in part from the left posterior cardinal vein.

Type AD occurs with relative frequency in the adult cat. Darrach found it in twenty cases (3.3 per cent) of his series of 605 adults. In the cat it was first described by Hochstetter

('93), and later by Gage ('98), and McClure ('00). We know of but one instance on record in which it has been found in man. This is a case observed in an acardiac foetus by Gladstone (fig. 8, '12) and illustrated here by figure 25.

9. Persistence of right supracardinal vein. Normal vena cava posterior (inferior) in the cat and in man

Type B (B in fig. 1). Figures 26, cat (Darrach Series); 27, man (Flourens, '36); 28, man (Huntington Collection); 29, man (Huntington Collection); 30, man (Vesalius, 1543); 31, man (Froriep, '95), and 32, man (Huntington Collection)

In both cat and man the type of vena cava posterior represented by *Type* B is one in which, caudal to the renal veins, the cava is single and lies on the right side of the abdominal aorta. The right sex vein (V. spermatica interna) opens into the cava, slightly caudal to the level of the right renal vein, and the left sex vein into the left renal vein. On leaving the kidney, the right ureter extends directly to the bladder without passing between the aorta and the caval vein. *Type* B, in both cat and man, is due to the persistence in the adult of the right lumbar supracardinal vein (*Sprc. B*, fig. 1).

The sex veins in the cat are formed by the posterior cardinal and the subcardinal veins. An elongation of the right side of the renal collar (*Subc.Sprc.Anast.Dext.*, figs. 1 and 4), to the caudal border of which the posterior cardinal with its sex-vein tributary is attached, accounts for the entrance of the right sex vein into the cava, caudal to the level of the right renal vein. In the cat, after the loss of the left side of the renal collar (*Subc.Sprc.Anast.*, figs. 1 and 5), the left renal vein drains into the cava by the subcardino-posterior cardinal anastomosis (*Subc.Pc.Anast.*), to which the posterior cardinal with its sex-vein tributary is attached. In this manner may be explained the difference, which, in the cat, exists on opposite sides in the relations which the sex veins bear to the cava and to the left renal vein.

McClure and Butler ('25) have recently shown that in man the sex veins are derived exclusively from the subcardinal veins and that each subcardinal, near the intersubcardinal anastomosis at the renal level (McC. and B., *Anast.Int.Subc.,* figs. 14 and 17), makes a cranial and a caudal connection with the axial veins. As the entrance of the right sex vein into the cava is in the adult usually single and caudal to that of the right renal vein, the more caudal of these two embryonic connections is the one usually retained. On the left side, the subcardinal (sex vein), by a cranial and a caudal connection, opens directly into the intersubcardinal anastomosis, which, after the loss of the left side of the renal collar (McC. and B., *Anast.Subc.Sprc.Sin.,* fig. 17), becomes the proximal portion of the left renal vein. The more caudal of the two embryonic connections which the left subcardinal vein makes with the intersubcardinal anastomosis is in the adult the one ordinarily retained.

Figures 26 to 32, inclusive, all represent instances in which the cava has been formed by the right supracardinal vein (*B,* fig. 1); they also illustrate certain variant or atypical conditions of the internal spermatic (V. spermatica interna) and the renal veins.

In figure 26 is shown an anastomosis between the sex veins of opposite sides, due to the persistence in the adult cat of an anastomosis present in the embryo, between the right and the left subcardinal veins (*Int.Subc.Anast.,* fig. 1). Such an anastomosis between sex veins has not yet been observed in adult man. This is undoubtedly due to the fact that corresponding intersubcardinal anastomoses are not found in the embryo of man (McClure and Butler, '25).

Figures 27 to 30, inclusive, of adult man, show interesting atypical conditions of the internal spermatic or sex veins. In figures 27, 28, and 29, the right sex vein communicates both with the cava and with the right renal vein; in figure 28, in addition to the double connection on the right side, the left sex vein presents also a double communication with the left renal vein. All these multiple connections which the sex veins present in adult man are easily explained on the basis of the persistence of the corresponding multiple connections found in the embryo of man (McClure and Butler, '25, figs.

14 and 17). Also, it is to be observed in figures 28 and 29 that the internal spermatic arteries show certain variant forms. It is of interest here to call attention to what is probably the earliest recorded observation of an atypical condition of the internal spermatic veins in adult man. In his "De Humani Corporis Fabrica," published in 1543, Vesalius shows a figure of the male urinogenital system of man in which the left internal spermatic vein presents a double communication with the cava and the left renal vein. The figure published by Vesalius is reproduced in our figure 30. In another figure, of the female urinogenital system, published also in 1543, Vesalius shows a single right and a single left sex vein opening, respectively, into the cava, caudal to the renal level, and into the left renal vein. As this is the normal condition in man, the multiple connection which Vesalius figured for the left sex vein must have been recognized by him as atypical in form.

The two remaining figures of this series, figures 31 and 32, illustrate two different forms of atypical renal veins.

Soon after emerging from the kidney, the left renal vein in figure 31 (*Fall.I.,* Froriep, '95) receives the left sex vein and then extends, caudad and mesad, *dorsal* to the aorta, to open into the cava, at the level of origin of the inferior mesenteric artery. The distinguishing features of this variant left renal vein are that it passes dorsal, instead of ventral, to the aorta and joins the cava somewhat caudal to the usual level of the renal veins. Except when a complete embryonic renal collar persists in the adult (fig. 59), instances in which the left renal vein passes *dorsal* to the aorta are associated with the absence of the left subcardino-posterior cardinal anastomosis (*Subc.Pc.Anast.,* fig. 1). In such cases, blood from the left posterior cardinal (*Pc.*) and the left embryonic renal vein (*R.V.*) is conveyed by the left side of the renal collar (*Subc. Sprc.Anast.*) to the left supracardinal (*Sprc.*), which may retain a connection with the right supracardinal (cava), dorsal to the aorta (*Int.Sprc.Anast.*), at any level in the lumbar region, between the kidneys and the common iliac veins. In the case of the variant shown in figure 31, the cranial half of the left lumbar supracardinal forms the major portion of the left renal vein, which, caudal to the renal level and dorsal to the aorta, joins the caval vein. In this connection it is interesting to examine the conditions shown in figure 35. In this case, if the right renal vein were to give up its connection with the cava at the renal level, the right supracardinal, into which the right sex vein opens, would then function as a renal vein and, through its intersupracardinal anastomosis, would have the same relations to the sex vein, the aorta, and the vena cava, as does the left renal vein in figure 31. An essentially similar accessory left renal vein opening into the caval vein has been described by Watt ('20).

Another example of an atypical left renal vein is shown in figure 32. In this case, in addition to a right and a left renal vein that are typical in all respects in their relations to the cava and the sex vein, there is present an accessory left renal vein. On emerging from the left kidney, this accessory renal vein passes caudad and mesad to open into the cava, *ventral* to the aorta, at the point where the cava is joined by the common iliac veins. Since a typical renal vein is present on the left side, it is evident that this accessory renal vein cannot have been derived from the renal veins, which in the embryo open into the renal collar (McClure and Butler, '25). The only available embryonic pathways which could be retained in the formation of this accessory renal vein are the cardinal collateral (*C.C.,* figs. 1, 4, and 5) and the left subcardinal veins (*Subc.,* fig. 1). The manner in which its connection with the kidney came about is still problematical, although no doubt can exist about its cardinal collateral origin (*C.C.,* fig. 1) in the region where, ventral to the aorta, the accessory renal vein opens into the caval vein.

10. Persistence of right and left supracardinal veins

Type BC (*B* and *C* in fig. 1). Figures 33, 34, 35, man (Huntington Collection), 36, 37, 38, 39, 40, 41, 42, and 43, cat (Darrach Series)

The atypical venae cavae illustrated under *Type* BC present a variety of forms in which both the right and the left supracardinal veins of the embryo persist in the lumbar region, either wholly or only in part, in the adult cat and in man.

Figure 33 is perhaps a typical example of a case in which both lumbar supracardinal veins of the embryo have in their entirety been carried into the adult stage. In such cases the left cava (*C* in fig. 1) joins the cava of the right side (*B*), *ventral* to the aorta, and approximately at the level of the renal veins. As in all examples of *Type* BC, the ureters in figure 33 extend from the kidneys to the bladder without passing between the aorta and the caval (supracardinal) veins.

In figure 34, also of man, both lumbar supracardinals are present in their entirety and, as in figure 33, the left cava joins the cava of the right side, *ventral* to the aorta, at the level of the renal veins. A distinguishing feature of this variant, however, is that, functionally, the cava of the left side is the more important vessel of the two. Also, at about the middle of the lumbar region, the right cava receives a large spinal vein and, cranial to its union with this vein, the right cava is a vessel of much greater caliber than is that section of the cava which lies caudal to the spinal vein.

In figures 35 (man) and 36 (cat), both lumbar supracardinals are present in their entirety and, as in figures 33 and 34, the left cava joins the cava of the right side, *ventral* to the aorta, at the level of the renal veins. A distinguishing feature of these two variants is that, *dorsal* to the aorta, the right cava and the left again unite with each other, at a level somewhat caudal to that of the renal veins. This dorsal union between the two veins is due to the persistence of an intersupracardinal anastomosis (*Int.Sprc.Anast.*, figs. 1 and 3), which is present in the embryo, at different levels, between the supracardinals of opposite sides. Through the presence of this intersupracardinal anastomosis, dorsal to the aorta, between the cavae of opposite sides, one can in the lumbar region (figs. 35 and 36) distinguish between a cranial and a caudal section of the right and the left caval veins. This distinction is one of considerable importance, as it enables us to interpret correctly those cases in which the left lumbar supracardinal is retained only in part, and not in its entirety, as in figures 33, 34, 35, and 36. If we compare figure 37 with figure 36, it is evident that the paired condition of the caval veins in figure 37 has been brought about by the persistence of the cranial section of the right and the left supracardinal veins as seen in figure 36. It is quite possible, however, that the unpaired caudal section of the lumbar cava in figure 37, as is usually the case in the cat, may have been formed by a fusion of both lumbar supracardinal veins (see figs. 2 and 3, in which an extensive anastomosis, dorsal to the aorta, is present between the supracardinal veins of opposite sides). Be this as it may, a fusion between the supracardinals cranially has not occurred, so that we have here a condition in which a paired cava is present, due to the persistence of a cranial section of the right and the left supracardinal veins as shown in figure 37.

In a similar manner the series of variants of *Type* BC, illustrated by figures 38 to 43, inclusive, can be interpreted as cases in which the entire right lumbar supracardinal and only a caudal section of the left supracardinal vein have been retained. In figures 38, 39, and 40, in which an anastomosis at the iliac level, between the iliac veins of opposite sides, has not been formed, it is seen that the left supracardinal joins the right supracardinal, *dorsal* to the aorta, at a level somewhat caudal to that of the renal veins. If we compare the elongated left common iliac vein in these three variants (figs. 38, 39, and 40) with the caudal section of the left supracardinal (left common iliac vein) in figure 36, we observe that, as in the latter, the elongated left common iliac must have been formed to a large extent by the left supracardinal vein, and that its point of union with the right supracardinal, *dorsal* to the aorta, is determined in individual cases by the level at which an intersupracardinal anastomosis (*Int.Sprc. Anast.,* fig. 1) has been retained. In the composite diagram of the veins, figure 1, the line of development followed by the left cava in figures 38, 39, and 40 is along *C,* which, at different levels in individual cases, retains a connection, *dorsal* to the aorta, through an intersupracardinal anastomosis (*Int.Sprc.Anast.*) with the right supracardinal vein (*B*).

The variants shown of *Type* B in figures 41, 42, and 43 differ from those just described only in the presence of an additional anastomosis, dorsal to the aorta, at the iliac level (left common iliac vein in fig. 41), or, at the level of the iliolumbar veins (figs. 42 and 43), between the axial veins of opposite sides. If an anastomosis between the veins had not been established at the iliolumbar level in the variants shown in figures 42 and 43, there would have resulted an elongated left common iliac vein, similar to that seen in figure 40.

A double or paired vena cava posterior in the lumbar region (*Type* BC, fig. 1) is of relatively common occurrence as a variant both in the adult cat and in man, and is a type of cava normally met with in a number of mammalian forms. It has been found to occur normally in the adult of Phoca communis (von Baer, '35), Chalamydophorus truncatus (Hyrtl, '55), Phoca (spec.?), Halichoerus truncatus (Burow, '38); Phoca vitulina, Delphinium delphis, Dasypus setosus, Dasypus novemcinctus, Manis gigantea, Erinaceus europaeus, Pteropus edulis, Echidna setosa (Hochstetter, '93); Orycteropus (Beddard, '09), and probably in the elephant (Huntington and McClure).

In mammals other than man, a double posterior vena cava has been described occurring as a variant in the dog by Kerkring (1670); in the cat by Gage ('98), McClure ('00), Darrach ('07), Smallwood ('06), and Metcalf ('18); in Hylobates by Keith ('96); and in Didelphys virginiana by McClure ('03 and '06).

Among the early anatomists who have described or figured a double vena cava inferior as occurring in adult man are:

Blasius (1674), Petsche (1736), Wilde (1750), Timmermann (1750), Lobstein (1760), Meckel (1773), Pohl (1773), and Morgagni (1779). In more recent times it has been described or figured as occurring in adult man by: Alten ('13), Antonelli ('82), Augier ('09), Barkow ('66), Brin ('97), Broca ('52), Carrière ('14), Cousin ('98), Cruveilhier ('35), Farmer ('97), Fawcett ('98), Flesch ('76), Gérard ('03, '06, and '14), Gerlach ('85), Givens ('12), Gorron ('00), Gruber ('80 and '81), Hahn ('96), Huber, cited by Serres ('60), Johnston ('13), Kadyi ('81), Kollmann ('93), Lagneau ('53), Lauber ('01), Looney ('22), Le Gendre ('60), Leudet ('53), Lobstein ('30), Lucas ('16), Martin ('52), Meckel ('22), Nicolai ('86), Oberndorfer ('03), Osler ('78), Otto ('24), Pangratz ('94), Parsons ('96), Patten ('09), Roth, cited by Serres ('60), Quain ('44), Rischbieth ('14), Serres ('60), Shepherd ('90), Soemmerring (1800), Stark ('34), Stieda ('93), Tichomirow ('93 and '98), Wallin ('20), Walsham ('81), Walter ('84), Watt ('20), Waterston ('13), Wilbrand ('42), Zaaijer ('73), Zagorsky ('22), Zander ('92), Zander and Stieda ('92), Zimmermann, cited by Serres, and Zumstein ('95). Although from an historical standpoint the above list is in no sense complete, nevertheless it indicates the relative frequency with which this variant (*Type* BC) has been observed in adult man.

Variant conditions of the vena cava inferior in which the posterior cardinal veins are concerned are exceedingly rare in adult man (*Types* A, AB, ABC, ABD, AC, ACD, AD, BCD, BD, CD, and D, fig. 1). See table on page 48. McClure and Butler ('25) have explained why this is the case, on the supposition that, since the posterior cardinal veins lose their identity and disappear early in ontogeny, their chance of being carried into the adult stage is correspondingly slight. Be this as it may, this view coincides exactly with the conditions found in adult man, in which variant forms of the vena cava, as thus far observed, consist principally of cases in which only the supracardinals are involved (*B* and *C,* fig. 1).

11. Persistence of right and left supracardinal, and left posterior cardinal veins. Periureteric venous ring present on left side, through which ureter passes

Type BCD (*B, C,* and *D* in fig. 1)

So far as we are aware, no example of *Type* BCD has thus far been observed either in the adult cat or in man. An interesting example of *Type* BCD, however, in which the right and the left supracardinal and the left posterior cardinal veins are involved, has been found to occur as a transitory ontogenetic stage in a 17-mm. embryo of the cat. Here, in figures 44 and 45, of the right and the left sides, respectively, of a reconstruction of the veins, both supracardinals (*Sprc.Dext.* and *Sin.*) are still functional as embryonic caval veins and the left supracardinal (*Sprc.Sin.,* fig. 45), with the left posterior cardinal vein (*Pc.Sin.,* fig. 45), forms a complete periureteric venous ring through which the ureter passes. It is evident that, potentially, the condition presented in this embryo may be carried into the adult stage. The chances are, however, that if development had proceeded to the adult stage, only the right supracardinal (*Sprc.Dext.*, fig. 44) and the left posterior cardinal veins (*Pc.Sin.,* fig. 45) would have been retained to establish a cava of *Type* BD, as shown in figures 46 and 47. The large size of the right supracardinal (*Sprc.Dext.,* fig. 44) and the left posterior cardinal veins (*Pc. Sin.,* fig. 45) leads one to infer that blood would still be directed from the iliac veins into these two vessels, at the expense of the smaller left supracardinal (*Sprc.Sin.,* fig. 45) and the left side of the renal collar (*Subc.Sprc.Anast.,* fig. 45). Although *Type* BCD has not thus far been observed in the adult cat, it is of importance to recognize the fact that it is found in the embryo and is therefore potential in the adult.

12. Persistence of right supracardinal and left posterior cardinal veins

Type BD (*B* and *D* in fig. 1). Figures 46 and 47, cat (Darrach Series)

Type BD represents a case of double vena cava posterior. It differs from *Type* BC (fig. 33) in that the left cava has been derived from the left posterior cardinal (*D* in fig. 1), instead of from the left supracardinal vein (*C* in fig. 1). This is evident from the fact that the left ureter passes dorsal to the left cava and emerges between the aorta and the caval vein. On the right side the cava is normal, having been derived from the right supracardinal vein (*B* in fig. 1), as is indicated by the relation which the ureter bears to the right caval vein.

Darrach found only two examples of *Type* BD in his series of 605 adult cats, and both of these are shown here in figures 46 and 47. So far as we know, *Type* BD has not hitherto been described for cat or for man.

In figure 46, the right supracardinal and the left posterior cardinal veins are of equal caliber. As no communication exists between the iliac veins of opposite sides, each cava starts as a direct continuation of the common iliac vein. In figure 47, the right supracardinal forms the larger of the two caval veins. It starts from the iliac confluence and ascends on the right side of the aorta, passing ventral to a large aberrant renal artery. The left posterior cardinal, the smaller of the two caval veins, starts from the left iliac vein and ascends at first dorsal and then ventral to the ureter, to join the right cava, ventral to the aorta, approximately at the level of the renal veins. In both instances the sex veins, except for their duplicity on the left side, present normal relations to the caval veins.

Figures 48 and 49 represent, respectively, the right and the left sides of a reconstruction of the veins in a 23-mm. cat embryo. As shown in the figures, the right supracardinal (*Sprc.Dext.*, fig. 48) and the left posterior cardinal veins (*Pc.Sin.*, fig. 49) are the only vessels (cavae) concerned in returning blood to the intersubcardinal anastomosis (*Int. Subc.Anast.*, fig. 49) from the iliac veins. The type of vena cava represented at this stage of development is, therefore, *Type* BD—a condition which may have been only transitory in character or, if development had proceeded, might have been carried into the adult stage. This 23-mm. cat embryo is therefore another instance of the potential character of the embryonic venous system in relation to the establishment of atypical forms of caval veins.

13. Persistence of left supracardinal vein

Type C (*C* in fig. 1). **Figures 50 and 51, cat (Darrach Series)**

The vena cava posterior represented by *Type* C is a mirror picture of *Type* B. In *Type* C the vena cava is a single vessel, situated on the left side of the abdominal aorta, derived from the left embryonic supracardinal vein (*C* in fig. 1). As in all cases where the cava has been formed by a supracardinal, the ureter in *Type* C lies entirely free of the caval vein. The left sex vein opens into the cava caudal to the renal level, and the right sex vein opens usually into the right renal (fig. 50), though occasionally into the caval vein (fig. 51).

Figure 52 represents the left side of a reconstruction of the veins in a 45-mm. cat embryo. It is an example of a case in which the left supracardinal vein (*Sprc.,* fig. 52) has persisted to form the caval vein (*Type* C). It is of special interest as evidence that the opening of the left sex vein into the cava, caudal to the level of the renal veins (*R.V.*), has been brought about by an elongation of the lateral portion of the renal collar (*Subc.Sprc.Anast.*), to the caudal border of which the posterior cardinal vein (*Pc*), with its sex-vein tributary (*S.V.*), is attached.

The presence of a left-sided vena cava posterior of *Type* C is of relatively frequent occurrence in the adult cat. It was found by Darrach ('07) in twenty-one cases (3.4 per cent) of his series of 605 adults. Also, it has been observed in the cat by Gage ('98), McClure ('00), and Hunt ('19); and in Didelphys virginiana by McClure ('03 and '06). Among the earlier anatomists a left vena cava inferior (*Type* C) was observed in man by Wrisberg in 1778 and by Morgagni in 1779. In more recent times it has been described as occurring in man by Berthel ('01), Cameron ('11), Fränkel ('10), Georg ('06), Gérard ('08), Gladstone ('12), Grimsdale ('94), Gruber

('65), Harrison ('39), McWhinnie ('40), Oberndorfer ('03), Paterson ('01), Quain ('44), Waring ('94), and Zumstein ('95).

Type C and *Type* BC are the variants of the vena cava inferior which occur most frequently in adult man.

14. Persistence of left supracardinal and left posterior cardinal veins. Periureteric venous ring present on left side, through which ureter passes

Type CD (_C_ and _D_ in fig. 1)

No instance has thus far been described, either in the adult cat or in man, in which the left supracardinal and the left posterior cardinal veins have alone persisted to form a periureteric venous ring on the left side. *Type* CD is a mirror picture of *Type* AB (fig. 9), with the venous ring on the left instead of the right side. Two cases have been described in mammals in which a periureteric venous ring was present on the left side—but in combination, however, either with a supracardinal or with a supracardinal and a posterior cardinal on the right side. The two cases referred to were described, respectively, by Hochstetter ('93) in Erinaceus europaeus (*Type* ABCD) and by Metcalf ('18) in the cat (*Type* BCD). (See figure 17 of the present monograph, in which Metcalf's figure has been reproduced.) While the presence of a periureteric venous ring on the left side is of rare occurrence in the adult cat, it is always present in the embryo (fig. 45), and is therefore potential for the adult.

15. Persistence of left posterior cardinal vein

Type D (_D_ in fig. 1). Figure 53, cat (Darrach Series)

Type D is a mirror picture of *Type* A, in which the cava is formed by the right posterior cardinal vein. *Type* D represents a case in which, caudal to the renal level, the cava is single, and lies on the left side of the abdominal aorta, with the left ureter passing between the aorta and the caval vein (fig. 53). The position which the left ureter bears to the cava indicates that the latter was derived from the left posterior cardinal vein.

Type D was found by Darrach ('07) in twenty-one (3.4 per cent) of his series of 605 adult cats. Also, it has been described in the cat by Hunt ('19). With the exception of a very doubtful case mentioned by Lawrence in 1897, *Type* D has not thus far been found in man.

16. Persistence of embryonic supracardinal system of veins to form a continuous system of vessels in the lumbar and the thoracic regions, by means of which blood from the iliac region can be conveyed directly to the heart, without passing through the liver

(*B* and *C*, and supracardinal (azygos), *dext.* and *sin.*, in fig. 1). Figures 54, man (fig. 5, Fawcett, '98); 55, man (fig. 1, Lauber, '01); 56, man (fig. 3, Kollmann, '93); 57, man (Hochstetter, '93), and 58, cat (Princeton Morphological Museum, no. 1040)

This type of variant has been designated by previous writers as 'absence of vena cava posterior' and as 'persistence of posterior cardinal veins.' From the standpoint of its development, this variant in both cat and man is an example of the persistence of the supracardinal complex of veins which, in the embryo, extend as continuous channels through the lumbar and the thoracic regions. In both cat and man, the bilaterally symmetrical supracardinal veins of the embryo subsequently anastomose freely with each other, dorsal to the aorta, in both the thoracic and the lumbar regions, though in the latter, in man less freely than in the cat (McClure and Butler, '25). From this complex are typically derived in its lumbar segment (postrenal) the normal adult cava and, in the thoracic region, the azygos vein (Huntington and McClure, '20). When the supracardinal veins persist in the adult as a continuous system throughout the lumbar and the thoracic regions, blood from the iliac veins can be returned to the heart without passing through the liver. (See *B* and *C* and supracardinal (azygos) in fig. 1.)

As thus far observed in the adult cat and in man, all cases of atypical vena cava posterior, which result from the persistence in the lumbar and the thoracic regions of a continuous supracardinal system of veins, may be classed under two general groups:

Group I includes those cases in which blood from the iliac veins is returned to the heart by the supracardinal system of veins, as well as by the usual and normal route through the liver.

Group II includes those cases in which all blood from the iliac veins is returned to the heart by the supracardinal system of veins, and in which the usual and normal route through the liver, via the prerenal division of vena cava, has not been established.

Figures 54 and 55 are excellent examples of cases which fall within group I. In each instance blood from the iliac veins has, in returning to the heart, a choice of two routes: one through the liver, by the prerenal division of the vena cava, and the other, by the supracardinal system of veins, which open into the superior vena cava and into the left innominate vein. As shown in figure 54 (fig. 5, Fawcett, '98), the embryonic condition of a bilaterally symmetrical and continuous system of supracardinal veins in the lumbar and the thoracic regions has actually been carried into the adult stage. In this case the supracardinals are represented in the lumbar region by the right and the left caval veins (*Type* BC), and, continuous with the latter in the thoracic region, by the azygos veins. In addition to the supracardinals, there is present the prerenal division of the vena cava inferior. This vessel communicates with the supracardinals at the renal level, and from this point extends craniad through the liver to open into the right auricle. The left azygos has been designated by Fawcett (fig. 54) as a derivative of the left cardinal vein. This view we now know to be incorrect. With the exception of the proximal end of the right and the left azygos veins, which are derived from the posterior cardinal veins (*Pc.1* in fig. 1), the continuous channel in the lumbar and the thoracic regions on each side of the body has been derived from the supracardinal system of veins. In figure 55 (fig. 1, Lauber, '01) is shown a similar condition, less diagrammatically represented than in figure 54. In this instance the right and the left caval veins in the lumbar region (supracardinals, *Type* BC), incorrectly designated by Lauber as posterior cardinal veins, are directly continuous in the thoracic region with a single azygos vein, which, in the middle thoracic region, swings, dorsal to the aorta, from the left to the right side, and opens into the vena cava superior. This single azygos vein shows indications of having been formed by a fusion, dorsal to the aorta, between the supracardinal veins of opposite sides. In addition to the supracardinal line as a pathway for the return of blood to the heart from the iliac region, there is present also a typical vena cava inferior (*V.cava inf.,* fig. 55), which joins the supracardinal system at the renal level and, after passing through the liver, opens into the right auricle.

We now pass to a consideration of those cases which fall within group II. These are illustrated by figures 56, 57, and 58. Here the supracardinal system of veins has persisted in the adult and constitutes the sole and only direct main pathway by which blood is returned to the heart from the region of the body drained by the iliac veins. In all variants which fall under group II, the intrahepatic venous circulation, formed by the advehent portal and the revehent hepatic channels, is entirely independent of the systemic veins (supracardinals). In figure 58 are shown the portal vein entering the liver and the vena hepatica communis emerging from the liver and extending to the right auricle. An ontogenetic interpretation of this form of variant is relatively simple. During the course of normal development, a connection is established between the hepatic circulation and the systemic veins (right subcardinal), at a point designated the *hepato-subcardinal junction* (McClure, '06), so that blood is directed from the systemic veins to the heart through the liver. (See Huntington and McClure, '20, figs. 1 and 2.) Should this connection not be established, the only available pathway from the posterior region of the body to the heart would be by the supracardinal system of veins. If that portion of the vena cava inferior which extends between the hepatic veins (Vv. hepaticae) and the renal level had not developed, an essentially similar condition would then prevail, as is shown in figures 56, 57, and 58. An examination of figures 55 to 58, inclusive, shows variations in the extent to which the originally bilaterally symmetrical supracardinal veins of the embryo may be carried into the adult. In figure 54 the supracardinal system has been carried into the adult in essentially its embryonic form; in figures 55 and 56 the right and the left supracardinals are present in the lumbar region, while in the thoracic region only the caudal half of the left and the cranial half of the right supracardinal have been retained. In figure 57 the right supracardinal along its entire extent has been carried into the adult stage. In this instance a considerable portion of the left thoracic supracardinal has entered into the formation of the left renal vein.

The occurrence of variants of this character in the adult cat and in man serves as a complete confirmation of the presence in the embryo of a supracardinal system of veins, which constitutes a morphological unity, distinct from that of the embryonic posterior cardinal veins.

An examination of the literature shows that an atypical condition of the veins, which has been designated by previous writers either as 'absence of inferior vena cava' or as 'persistence of posterior cardinal veins,' has been described a number of times as occurring in man and, in a few cases, in other mammals, as follows:

1. In man, by Abernathy (1793), Barkow ('66), Benöhr ('04), Bujalsky ('29), Carpentier et Bertaux ('88), Cruveilhier ('71), Dorsch ('58), Dwight ('01), Goettsch ('20), Gurlt ('19), Herholdt ('32), Hochstetter ('93), Horner ('17), Hyrtl ('39), Kaestner ('00), Lauber ('01), Klob ('59), Kollmann ('93), Lawrence ('19), Martin ('62), McWhinnie ('40), Moser ('48), Neuberger ('13), Osler ('78), Otto ('24), Paulus ('42), Quain ('44), Revell ('03), Tourneux et Wertheimer ('82), Virchow ('61), Wertheimer ('80), Winslow (1775), and Wistar (1827).

2. In mammals other than man, it has been described in the cat, by Huntington and McClure, Pearl ('08), and Hunt ('19); in the dog, by Ponsot ('56), Körösy ('10), and Cooper ('20); in the deer (Cervus tarandus), by Barkow ('66); and in the guinea-pig (Cavia) by Phisalix ('98).

17. Persistence of renal collar (circumaortic venous ring at level of renal veins)

See renal collar in figure 1. Figure 59, man (Huntington Collection)

The renal collar is a term used by Huntington and McClure to designate an extensive embryonic venous ring, which, like a collar, encircles the aorta, at the level of the renal veins. In the embryo of the cat (fig. 1) the renal collar is formed ventrally by the intersubcardinal anastomosis (*Int.Subc. Anast.*) and the right and the left subcardino-posterior cardinal anastomoses (*Subc.Pc.Anast.*); laterally, by the right and the left subcardino-supracardinal anastomoses (*Subc. Sprc.Anast.*); and dorsally, by the intersupracardinal anastomosis (*Int.Sprc.Anast.*) between the supracardinal veins. The renal collar serves in the embryo as a common meeting place for all main axial venous channels and is a region toward which blood is directed from the systemic veins to the heart, by way of the liver, through the prerenal division of the vena cava posterior (*P.Subc.* and *P.Hep.,* fig. 1). In transforming from the embryonic to the adult condition, the renal collar early loses its ring-like character, and only a portion of it is retained in the adult cat, where it enters into the formation of the left renal vein (*Subc.Pc. Anast.Sin*) and of a small segment of the vena cava posterior (*Subc.Sprc.Dext.,* fig. 1). For further details the reader is referred to the article by Huntington and McClure ('20), on "The development of the veins in the domestic cat."

In figure 59 we have represented an instance in which the renal collar, in essentially its embryonic condition, has persisted in adult man. In two other cases observed in man, one shown in figure 35 and the other figured by Oberndorfer ('03), the aorta is encircled by a venous ring, but not in so typical a form at the renal level as that shown in figure 59. In all three cases, however, the portion of the venous ring which lies dorsal to the aorta has resulted from the persistence of an intersupracardinal anastomosis (*Int.Sprc.Anast.,* fig. 1), between the supracardinal veins.

The three cases above mentioned represent the only instances on record in which a venous ring, encircling the aorta at or near the renal level, has been carried into the adult.

18. Persistence of subaortic plexus (*embryonic cardinal collateral veins*)

Marsupial Type of vena cava posterior. (See *C.C.* in fig. 1 and in figs. 4 and 5, for cardinal collateral veins). Figure 61, cat (Darrach Series); 62, cat (Princeton Morphological Museum, no. 603), and 63, man (Wicke, '27)

In most placental mammals the iliac veins unite to form the vena cava posterior *dorsal* to the aorta and to the iliac arteries; and, between the iliac and the renal veins, the cava lies free of the ureter and to the *right* of the aorta. This is the type of cava (*Type* B) which is ordinarily met with in placental mammals. On the other hand, in most of the Australian marsupials, the iliac veins unite to form the vena cava posterior *ventral* to the aorta and to the iliac arteries; and, between the iliac and the renal veins, the cava lies free of the ureters and *ventral* to the aorta. A comparison of figure 26 of the cat with figure 60 of an Australian marsupial (Petrogale) clearly illustrates the difference between the typical vena cava posterior of a placental mammal (*Type* B) and that of a marsupial.

In both cat (Huntington and McClure, '20) and man (McClure and Butler, '25) the umbilical arteries of the embryo are at one time encircled by venous rings, the ventral circumference of which is formed by a vein, designated cardinal collateral vein (*C.C.* in fig. 1). The term *cardinal collateral* was first applied by McClure ('06), in marsupials, to certain embryonic veins, distinct from the posterior cardinals. In the lumbar region these veins lie ventrolateral and ventral to the aorta, and *ventral* to the umbilical arteries. In the adult marsupial, these give rise in the lumbar region to the vena cava posterior. The cardinal collaterals in the embryo cat (*C.C.*, figs. 1, 4, and 5), as in marsupials, lie ventral and ventrolateral to the aorta and extend throughout the lumbar region, between the iliac and the renal veins (*C.C.* in figs. 4 and 5). While typical circumumbilical venous rings are present in the human embryo, the cardinal collateral system of veins in the lumbar region between the iliac and the renal veins is not so prominently developed in the embryo of man as in that of the cat (McClure and Butler, '25). Since cardinal collateral channels are normally met with during the course of ontogeny, they like other normal embryonic veins are potential in the adult stage. As a matter of fact, we know of four such instances, two in the cat and two in man.

Figure 61 represents a case in which the embryonic cardinal collateral (*C.C.* in fig. 1), in conjunction with the right and the left posterior cardinal veins (*A* and *D* in fig. 1), has persisted in an adult cat. The vena cava posterior represented by this variant is one which we may regard as being a combination of *Type* AD and of the so-called *Marsupial Type*. If we compare figures 18 and 19, each of which is a good example of *Type* AD, with figure 61, we observe that in one case the iliac veins unite *dorsal,* and in the other, *ventral* to the aorta, to form the vena cava posterior. Also, if we compare the variant in figure 61 with the marsupial cava in figure 60, we observe that, with exception of the relation which the right ureter bears to the right caval vein, the conditions are in each case identical, as regards the relations between the aorta and the right caval vein.

In the preceding pages we have seen that there are fifteen ways in which the lumbar cava may be formed and carried into the adult stage, due to the persistence of one or more of the embryonic right and left supracardinal and the embryonic right and left posterior cardinal veins. It is therefore evident we may rightly expect that the cardinal collateral vein (*C.C.* in fig. 1) might persist in the adult cat in conjunction with any one of these fifteen possibilities or *Types* of caval veins. Such being the case, if the right supracardinal (*B* in fig. 1) had persisted in the variant (fig. 61) in place of the right posterior cardinal, the relations of the cava to the ureter and the aorta would in the variant and the marsupial have been exactly the same.

Another example of a case in which the cardinal collateral vein of the embryo (*C.C.*) has been retained in an adult cat is shown in figure 62. Also, a case identical to this has been described and figured by Johnston ('13, p. 235), as occurring in adult man. While these two cases are not so typical as that shown in figure 61, nevertheless they represent instances in which a vein, extending ventral to the aorta between the left iliac and the caval veins (right supracardinal, *Type* B), has been derived from the ventral portion of the embryonic circumumbilical venous rings (*C.C.* in fig. 1). An analysis of figure 1 clearly shows the possibilities which exist as regards the persistence of such a ventral venous channel as that shown in figure 62. Its origin from the cardinal collateral vein of the embryo is the only plausible explanation of its presence in the adult cat and in man.

Another example of the *Marsupial Type* has more recently been described and figured for adult man by Wicke ('27).[7] In this case (fig. 63), a periureteric venous ring, through which the ureter passes, is present on the right side (*Type* AB); in addition to this venous ring, however, there is present a persistent cardinal collateral channel, represented by the left common iliac vein (*V.il.c.s.*), which passes *ventral* to the right common iliac artery (*A.il.c.d.*), to become directly continuous with the right posterior cardinal vein (*V.cv.v.*).

[7] Über einen Fall von Inselbildung im Bereiche der hinteren Hohlvene (Vena cava posterior) und Durchtritt des rechten Harnleiters beim Erwachsenen. Zeitsch. für Anat. und Entwicklungsgesch., Bd. 84, S. 524–533.

This paper did not appear until after Doctor Huntington's death. Also, since 1927, two other important papers have appeared dealing with atypical conditions of the vena cava posterior:

Maxwell, E. V., and Erwin, G. S. 1928. Four cases of anomalous inferior vena cava with an explanation of their development. Jour. Anat., vol. 62, pp. 184–197.

Kadletz, M. 1928. Über eine Missbildung im Bereich der Vena cava caudalis beim Hunde. Zeitsch. für Anat. und Entwicklungsgesch., Bd. 88, S. 385–396.

The ventral position occupied by the left common iliac vein clearly indicates that it has been derived from the ventral portion of the embryonic circumumbilical venous rings (*C.C.* in fig. 1). Furthermore, the presence of the anastomosis between the right and the left common iliac veins (*V.cm.cd.*) indicates the persistence of a complete embryonic circumumbilical venous ring on the right side, as is shown in the composite diagram of the veins (*C.C.*, fig. 1).

It is of interest here to note that during the course of this investigation our prediction that a cava of the *Marsupial Type* would be found in both cat and man has been completely fulfilled.

The table that follows shows the relative frequency with which the different types of vena cava posterior have been observed to occur in the adult cat and in man. The data for the cat include those cases observed by Darrach in his series of 605 adults, as well as those recorded in the literature by other investigators. The data for man include cases which have been recorded in the literature available to us. While the table is in no sense to be regarded as complete, it nevertheless brings out many interesting points regarding the relative distribution of the different types of venae cavae as thus far determined by us in the cat and in man.

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VII. TABLE SHOWING RELATIVE FREQUENCY WITH WHICH THE DIFFERENT *TYPES* OF VENA CAVA POSTERIOR HAVE BEEN OBSERVED TO OCCUR IN THE ADULT CAT AND IN MAN

TYPE	CAT	MAN
A	24	4
AB	4	1
ABC	1	0
ABCD	0	0
ABD	0	0
AC	5	0
ACD	1	0
AD	23	1
B	Normal vena cava	Normal vena cava
BC	14	71
BCD	0	0
BD	2	0
C	24	17
CD	0	0
D	22	1(?)
Persistent supracardinal system	3	33
Persistent renal collar	0	3
Marsupial Type	2	2

VIII. GENERAL CONCLUSIONS

In the preceding pages we have demonstrated that all atypical conditions of the vena cava posterior (inferior) found in the adult cat and in man can be interpreted and explained on the basis of the modifications of a common ontogenetic plan of the veins. An analysis of the composite diagram (fig. 1) of the embryonic veins shows that seventeen (17) predictable forms of atypical venae cavae occur. In conclusion, we may state that every atypical condition of the vena cava thus far observed in the cat and in man falls within one of the seventeen predictable *Types* of caval veins.

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X. ABBREVIATIONS

A., lumbar division of right posterior cardinal vein (V. cardinalis posterior dextra)

Adr., adrenal vein (V. adrenalis, suprarenalis)

A.Om., omphalomesenteric artery (A. omphalomesenterica)

Ao., aorta

B., lumbar division of right supracardinal vein (V. supracardinalis dextra)

C., lumbar division of left supracardinal vein (V. supracardinalis sinistra)

C.C., ventral portion of circumumbilical venous ring in figure 1 (V. cardinalis collateralis). Also V. cardinalis collateralis in figures 4 and 5

D., lumbar division of left posterior cardinal vein (V. cardinalis posterior sinistra)

D.C., duct of Cuvier (V. cardinalis communis)

E.Il.V., external iliac vein (V. iliaca externa)

I.Il.V., internal iliac vein (V. iliaca interna)

Int.Sprc.Anast., intersupracardinal anastomosis. Anastomosis, dorsal to aorta, between supracardinal veins

Int.Subc.Anast., intersubcardinal anastomosis. Anastomosis, ventral to aorta, between subcardinal veins

K., permanent kidney (metanephros)

L.Innom.V., left innominate vein (V. anonyma sinistra)

P.Hep., pars hepatica of vena cava posterior

P.Subc., pars subcardinalis of vena cava posterior

Pc., posterior cardinal vein (V. cardinalis posterior)

Pc.1., thoracic division of posterior cardinal vein forming cranial end of azygos vein

Pc.2.Dext., lumbar division of right posterior cardinal vein entering into formation of right periureteric venous ring

Pc.2.Sin., lumbar division of left posterior cardinal vein entering into formation of left periureteric venous ring

Pc.Sprc.Anast., posterior cardinal-supracardinal anastomosis (anastomosis between posterior cardinal and supracardinal veins)

R.V., embryonic renal vein

Sprc., supracardinal vein (V. supracardinalis)

Sprc.Dext.(*P.Sprc.*), right supracardinal vein (pars supracardinalis of vena cava posterior)

Subc., subcardinal vein (V. subcardinalis)

Subc.Pc.Anast., subcardino-posterior cardinal anastomosis. Anastomosis between subcardinal and posterior cardinal veins

Subc.Sprc.Anast., subcardino-supracardinal anastomosis. Anastomosis between subcardinal and supracardinal veins

S.V., sex vein (V. spermatica interna)

Ur., ureter

V.Sper.Int., sex vein (V. spermatica interna)

XI. PLATES

PLATE I

EXPLANATION OF FIGURE[9]

1 Composite diagram of embryonic veins of the domestic cat (Felis domestica), based on a detailed study of the development of the veins.

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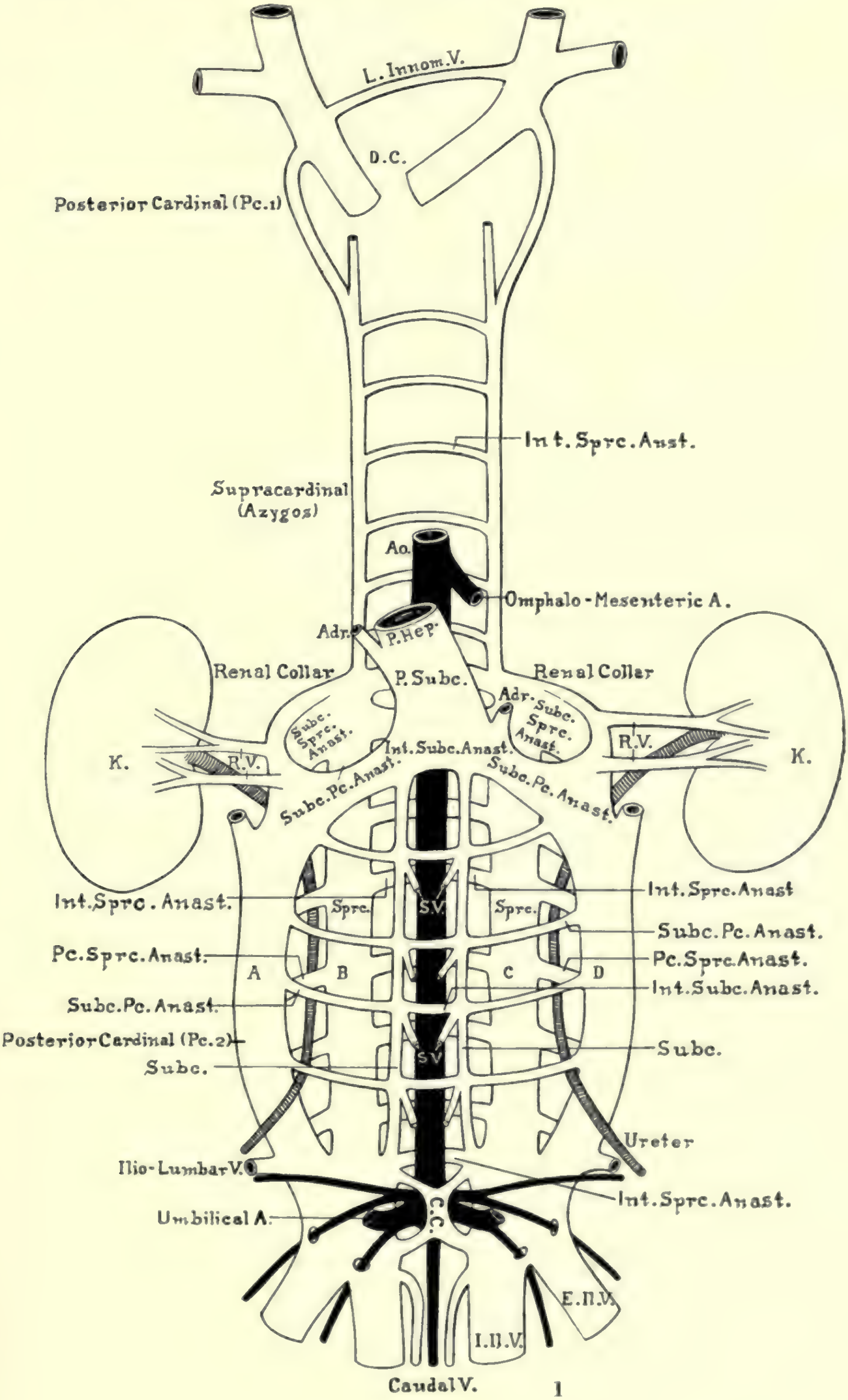
[9] The figures in this memoir were drawn by Mr. M. Petersen, of the College of Physicians and Surgeons of Columbia University.


L. Innom.V.
D.C.
Posterior Cardinal (Pc.1)
Int. Sprc. Anst.
Supracardinal
(Azygos)
Ao.
Omphalo-Mesenteric A.
Adr.
P. Hep.
Renal Collar
P. Subc.
Renal Collar
Adr.
Subc. Sprc. Anast.
Subc. Sprc. Anast.
R.V.
R.V.
K.
K.
Int. Subc. Anast.
Subc. Pc. Anast.
Subc. Pc. Anast.
Int. Sprc. Anast.
Sprc.
S.V.
Sprc.
Int. Sprc. Anast
Subc. Pc. Anast.
Pc. Sprc. Anast.
Pc. Sprc. Anast.
A
B
C
D
Int. Subc. Anast.
Subc. Pc. Anast.
Posterior Cardinal (Pc.2)
S.V.
Subc.
Subc.
Ureter
Ilio-Lumbar V.
Int. Sprc. Anast.
Umbilical A.
C.C.
E.II.V.
I.II.V.
Caudal V.

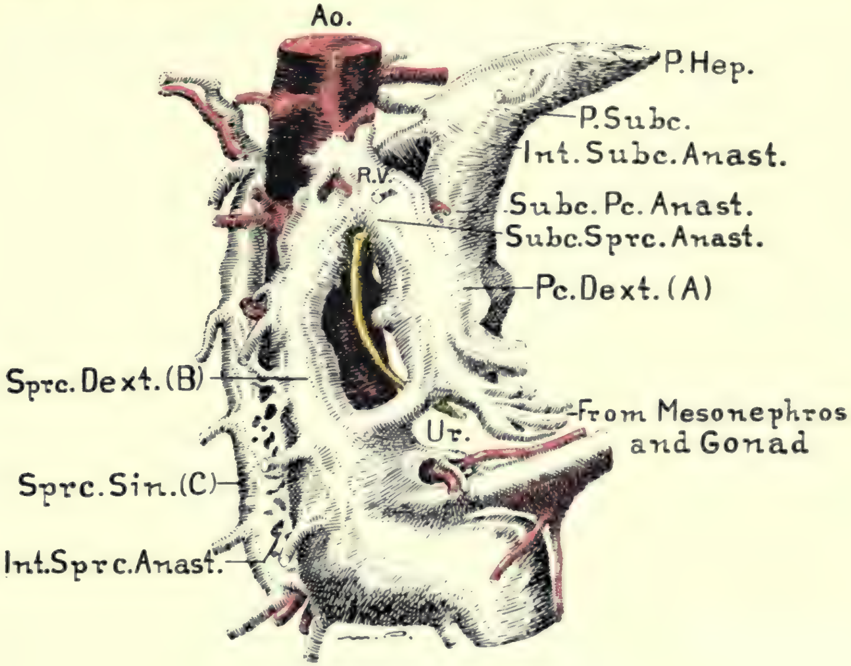
1

PLATE II

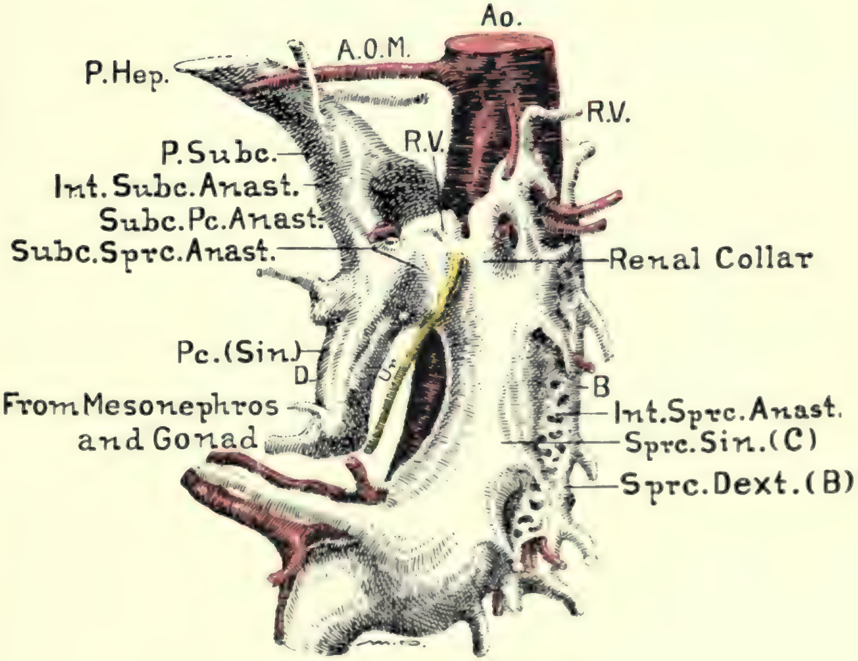
EXPLANATION OF FIGURES

2 Reconstruction (after Born) of veins in the lumbar region of a 16-mm. cat embryo. Lateral aspect, *right* side, showing the right posterior cardinal (*A*), the right supracardinal (*B*), the left supracardinal (*C*), the right periureteric venous ring, through which the ureter (*Ur.*) passes, and the left side of the renal collar (*Subc.Sprc.Anast.*). Princeton Embryological Collection, no. 15.

3 Reconstruction (after Born) of veins in the lumbar region of a 16-mm. cat embryo. Lateral aspect, *left* side, showing the left posterior cardinal (*D*), which has lost its caudal connection with the left supracardinal (*C*), so that a periureteric venous ring is not present on the left side. The left posterior cardinal (*D*), with its subcardinal sex-gland tributaries, forms the left V. spermatica interna in the adult. The right posterior cardinal (*A*, fig. 2) similarly forms the vena spermatica of the right side. Note that the posterior cardinals (*A* and *D*), on either side of the body, joins the caudal border of the lateral portion of the renal collar (*Subc.Sprc.Anast.*) and that the right and the left supracardinals (*B* and *C*) anastomose with each other, dorsal to the aorta, by intersupracardinal anastomoses (*Int.Sprc.Anast.*). The vena cava in this embryo is still in a transitory state of development and at present is represented by a cava of *Type* ABC. Princeton Embryological Collection, no. 15.


Ao.
P.Hep.
P.Subc.
Int.Subc.Anast.
R.V.
Subc.Pc.Anast.
Subc.Sprc.Anast.
Pc.Dext.(A)
Sprc.Dext.(B)
From Mesonephros and Gonad
Ur.
Sprc.Sin.(C)
Int.Sprc.Anast.

2


Ao.
A.O.M.
P.Hep.
R.V.
P.Subc.
R.V.
Int.Subc.Anast.
Subc.Pc.Anast.
Subc.Sprc.Anast.
Renal Collar
Pc.(Sin.)
D.
Ur.
B
From Mesonephros and Gonad
Int.Sprc.Anast.
Sprc.Sin.(C)
Sprc.Dext.(B)

3

PLATE III

EXPLANATION OF FIGURE

4 Reconstruction (after Born) of veins in the lumbar region of a 29-mm. cat embryo. Lateral aspect, *right* side, showing the cardinal collateral system of veins (*C.C.*), which extend, ventral and ventrolateral to the aorta, between the iliac and renal levels. Note the right vena spermatica interna (*Pc.2.Dext.*) and its relations to the ureter (*Ur.*) and to the lateral portion of the renal collar (*Subc.Sprc.Anast.Dext.*). Coll. of P. and S. Embryological Collection, no. 575.[10]

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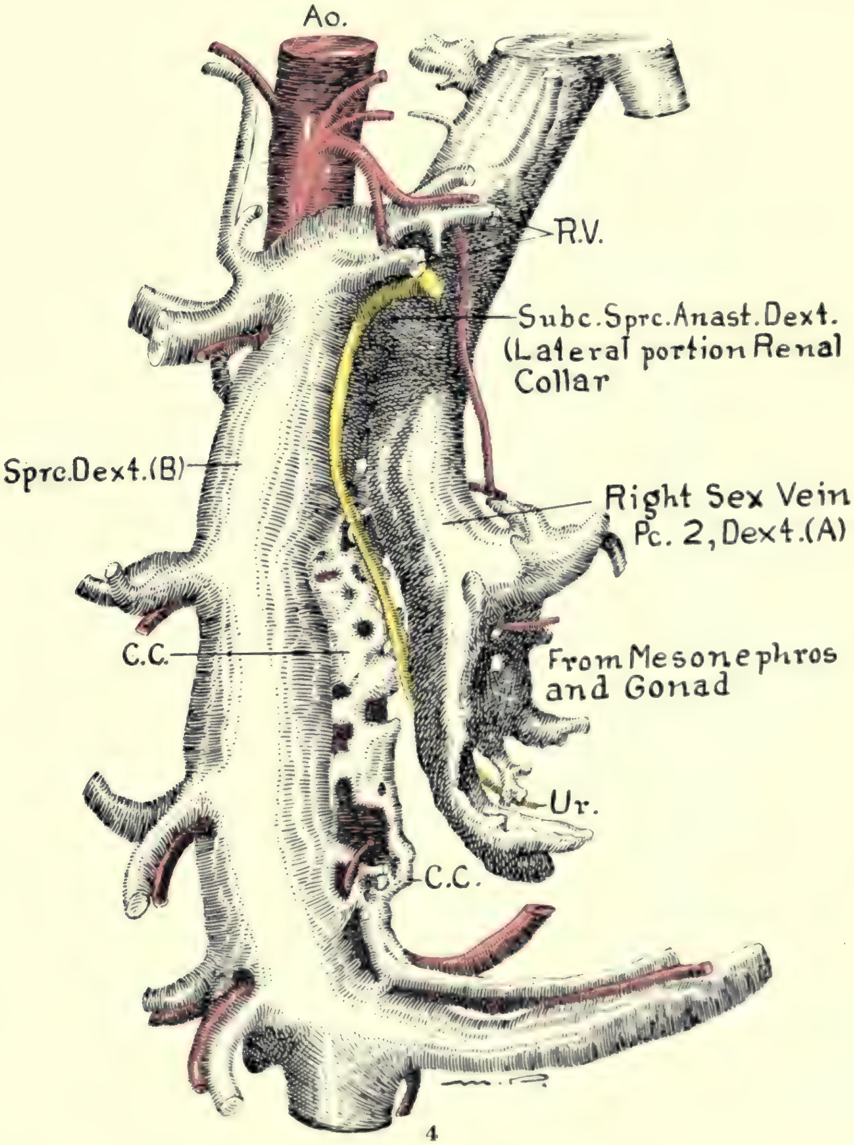
[10] College of Physicians and Surgeons of Columbia University.

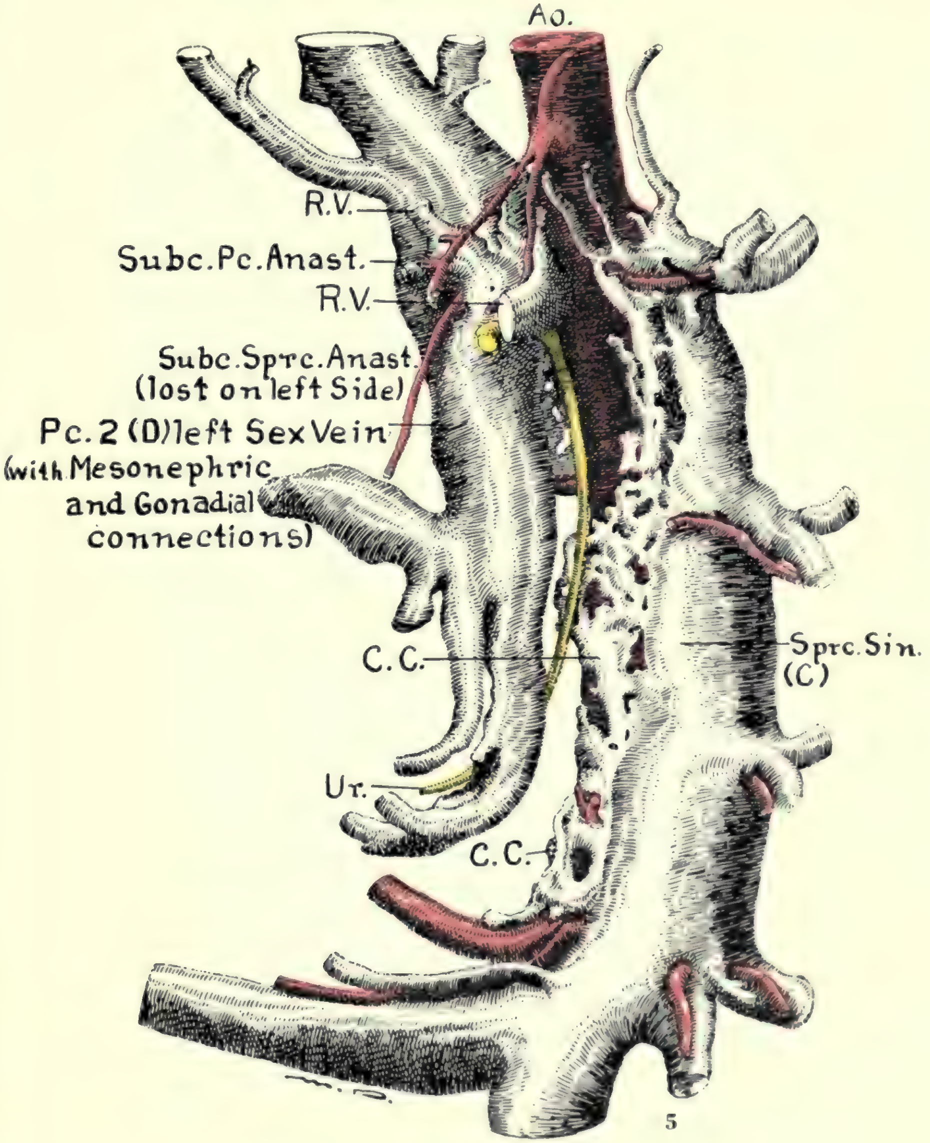

Ao.
R.V.
Subc. Sprc. Anast. Dext.
(Lateral portion Renal
Collar
Sprc. Dext. (B)
Right Sex Vein
Pc. 2, Dext. (A)
C.C.
From Mesonephros
and Gonad
Ur.
C.C.

4

PLATE IV

EXPLANATION OF FIGURE

5 Reconstruction (after Born) of veins in the lumbar region of a 29-mm. cat embryo. Lateral aspect, *left* side, showing cardinal collateral system of veins (*C.C.*), and complete atrophy of left side of renal collar (*Subc.Sprc. Anast.*). Note that, with the loss of the left side of the renal collar, blood in the left supracardinal (*C*) is directed into the right supracardinal, through the dorsal intersupracardinal anastomoses, present between the right and the left supracardinal veins. At the present stage of development the cava in the lumbar region appears to be formed through a fusion of both supracardinal veins. Coll. of P. and S. Embryological Collection, no. 575.

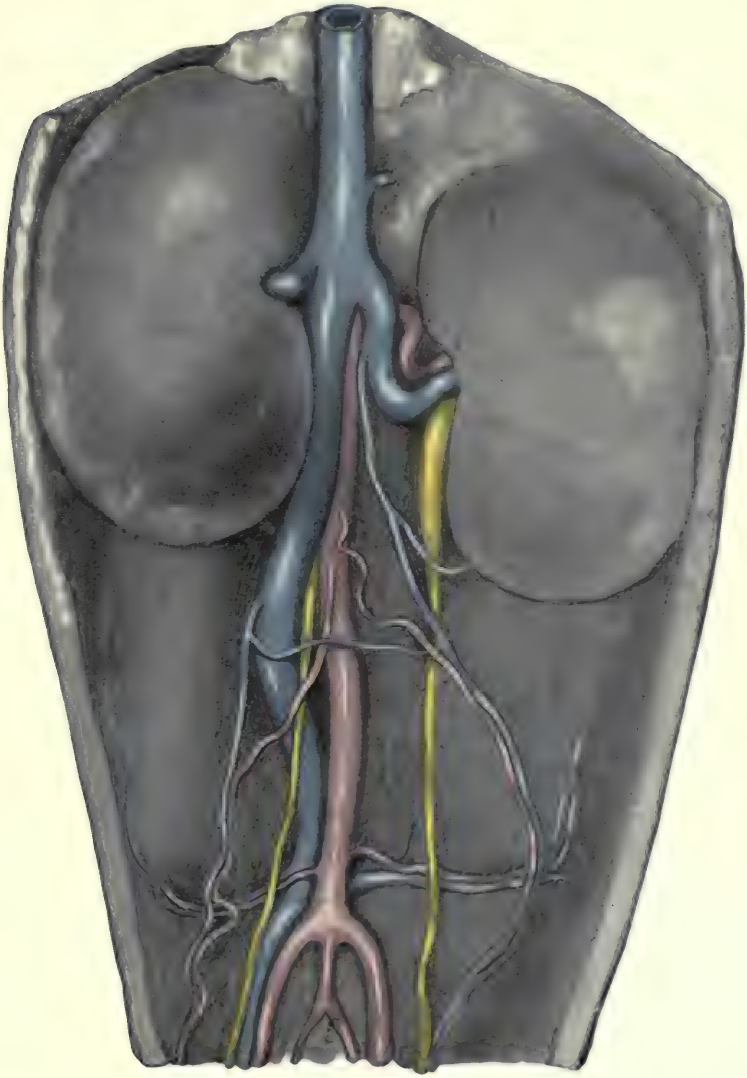

Ao.
R.V.
Subc.Pc.Anast.
R.V.
Subc.Sprc.Anast.
(lost on left Side)
Pc.2 (D) left Sex Vein
(with Mesonephric
and Gonadial
connections)
C.C.
Sprc.Sin.
(C)
Ur.
C.C.

5

PLATE V

EXPLANATION OF FIGURE

6 Adult cat (Darrach Series), *Type* A. Persistence of right posterior cardinal vein.



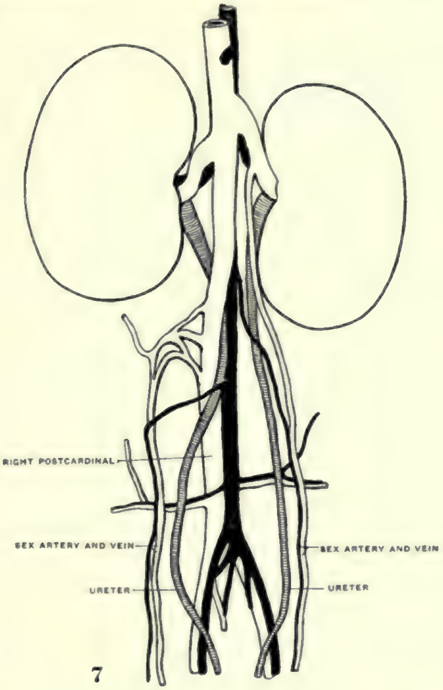
6

PLATE VI

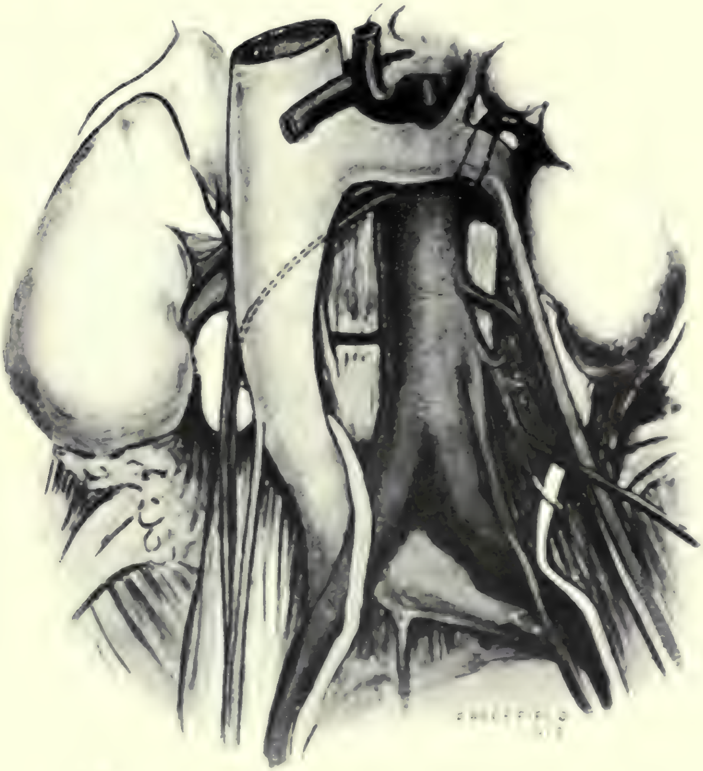
EXPLANATION OF FIGURES

7 Adult cat (Darrach Series), *Type* A. Persistence of right posterior cardinal vein.

8 Adult man (Gladstone, fig. 1, '12), *Type* A. Persistence of right posterior cardinal vein.


RIGHT POSTCARDINAL
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
URETER
URETER

7

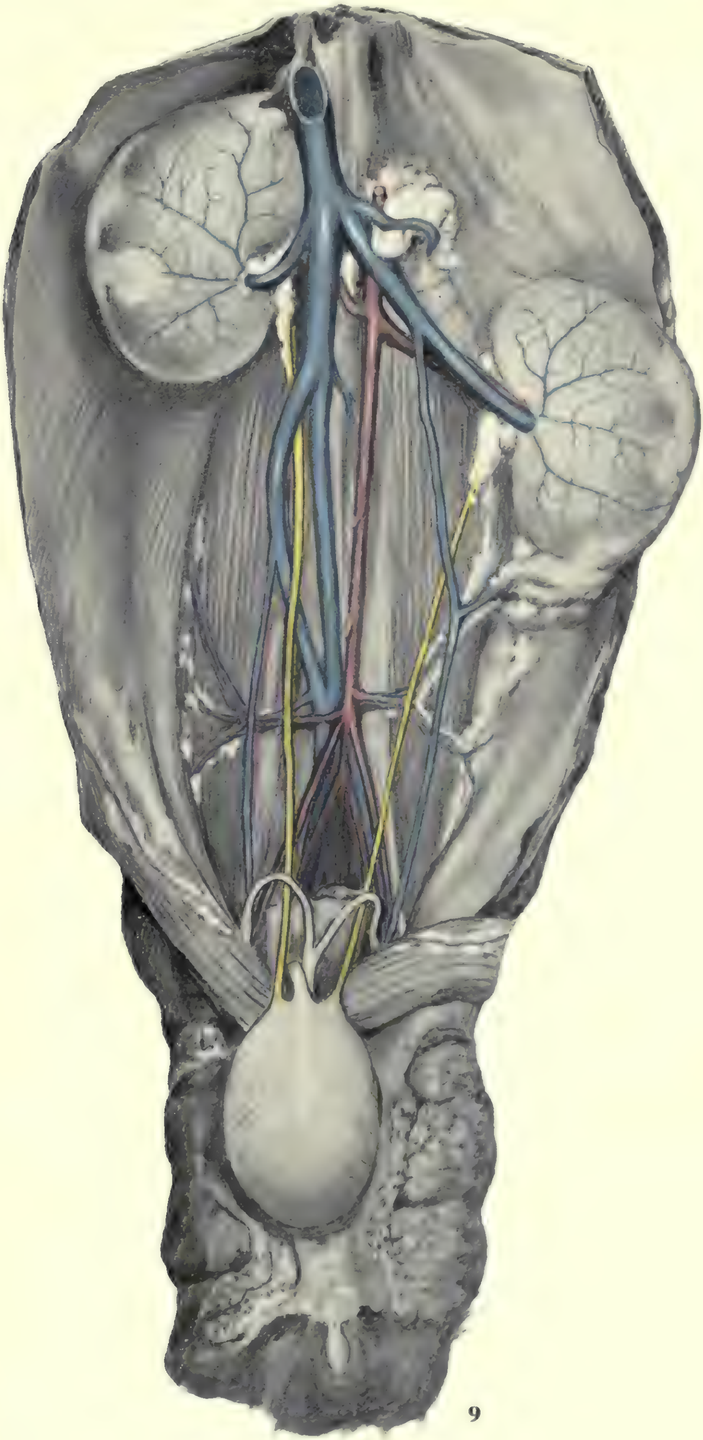


8

PLATE VII

EXPLANATION OF FIGURE

9 Adult cat (Darrach Series), *Type* AB. Persistence of right posterior cardinal and right supracardinal veins. Periureteric venous ring, through which ureter passes, present on right side.



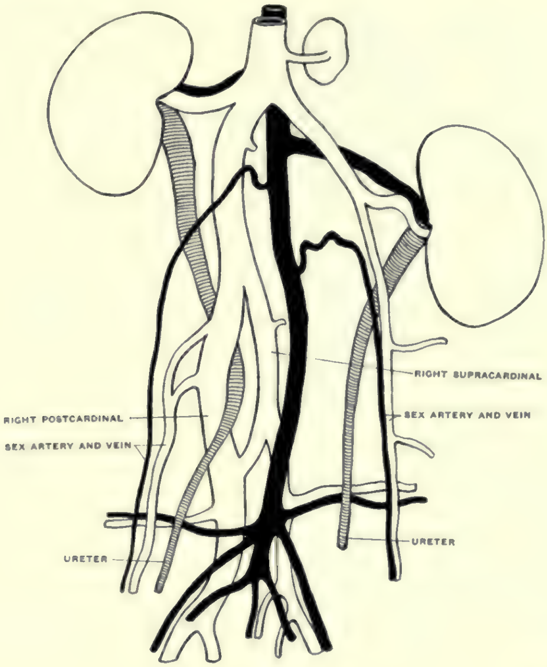
9

PLATE VIII

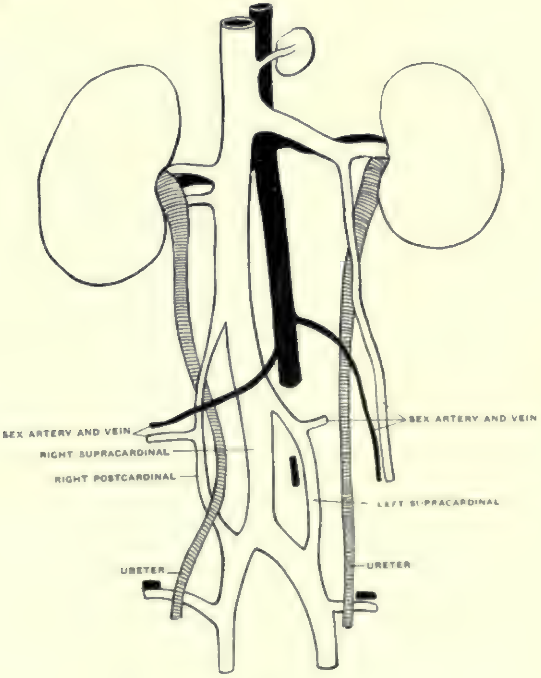
EXPLANATION OF FIGURES

10 Adult cat (Darrach Series), *Type* AB. Persistence of right posterior cardinal and right supracardinal veins. Periureteric venous ring, through which ureter passes, present on right side.

11 Adult cat (Darrach Series), *Type* ABC. Persistence of right posterior cardinal, right supracardinal, and left supracardinal veins. Periureteric venous ring, through which ureter passes, present on right side.


RIGHT SUPRACARDINAL
SEX ARTERY AND VEIN
RIGHT POSTCARDINAL
SEX ARTERY AND VEIN
URETER
URETER

10


SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
RIGHT SUPRACARDINAL
RIGHT POSTCARDINAL
LEFT SUPRACARDINAL
URETER
URETER

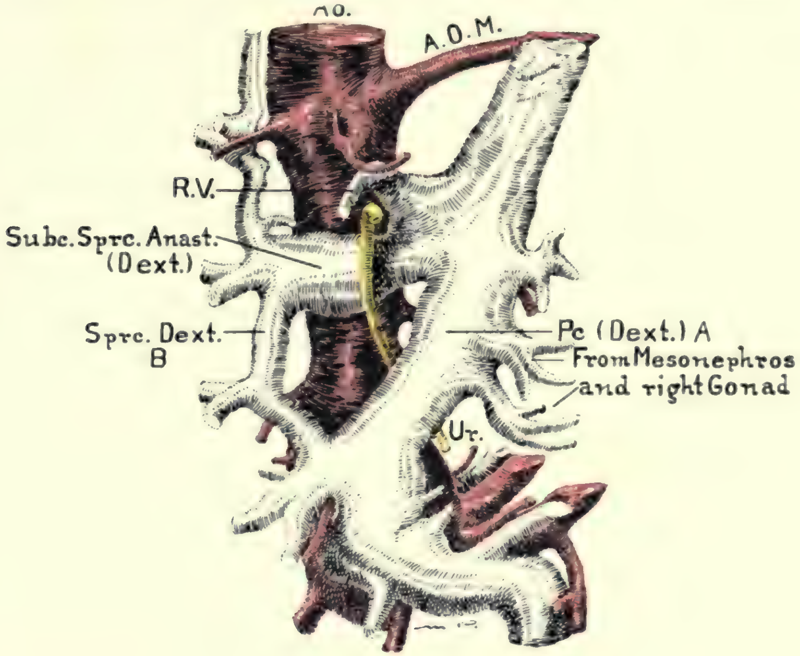
11

PLATE IX

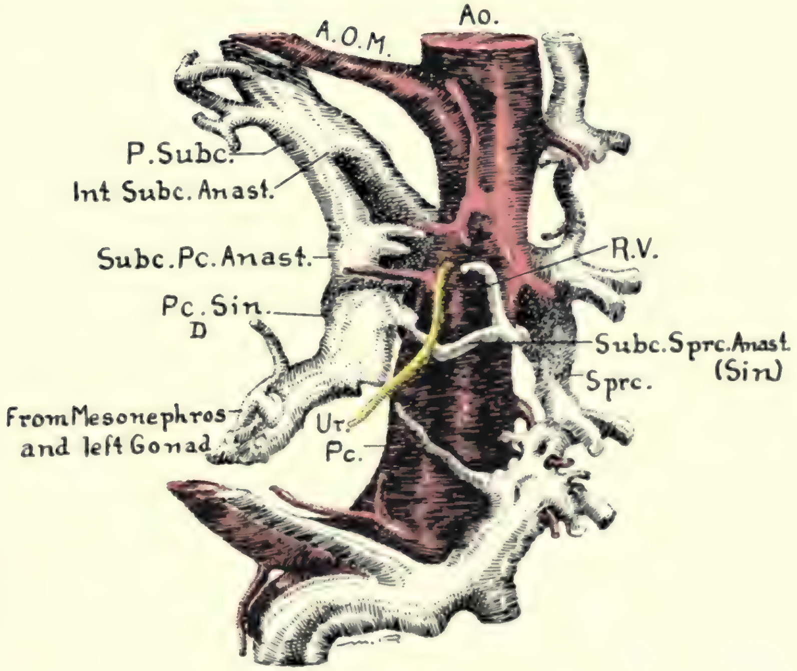
EXPLANATION OF FIGURES

12 Reconstruction (after Born) of veins in the lumbar region of a 21-mm. cat embryo. Lateral aspect, *right* side. Periureteric venous ring, through which ureter passes, present on *right* side. Coll. of P. and S. Embryological Collection, no. 242.

13 Reconstruction (after Born) of veins in the lumbar region of a 21-mm. cat embryo. Lateral aspect, *left* side. Coll. of P. and S. Embryological Collection, no. 242.


Ao.
A.O.M.
R.V.
Subc.Sprc.Anast.
(Dext.)
Sprc. Dext.
B
Pc (Dext.) A
From Mesonephros
and right Gonad
Ur.

12


A.O.M.
Ao.
P.Subc.
Int Subc. Anast.
Subc.Pc.Anast.
R.V.
Pc.Sin.
D
Subc.Sprc.Anast
(Sin)
Sprc.
From Mesonephros
and left Gonad
Ur.
Pc.

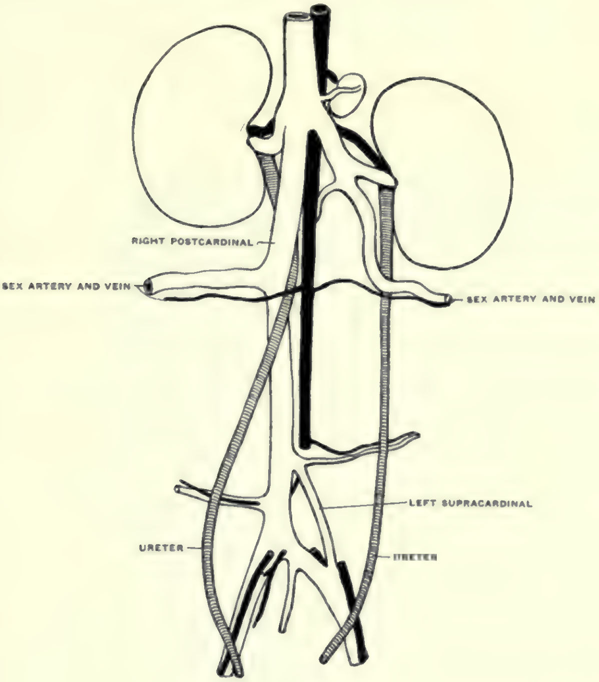
13

PLATE X

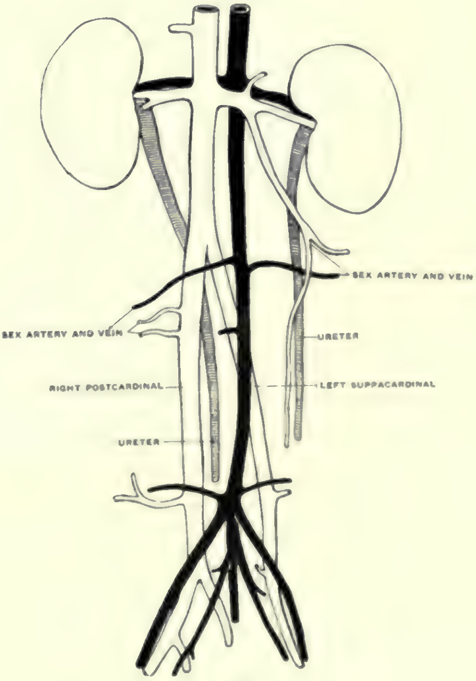
EXPLANATION OF FIGURES

14 Adult cat (Darrach Series), *Type* AC. Persistence of right posterior cardinal and left supracardinal veins.

15 Adult cat (Darrach Series), *Type* AC. Persistence of right posterior cardinal and left supracardinal veins.


RIGHT POSTCARDINAL
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
LEFT SUPRACARDINAL
URETER
URETER

14

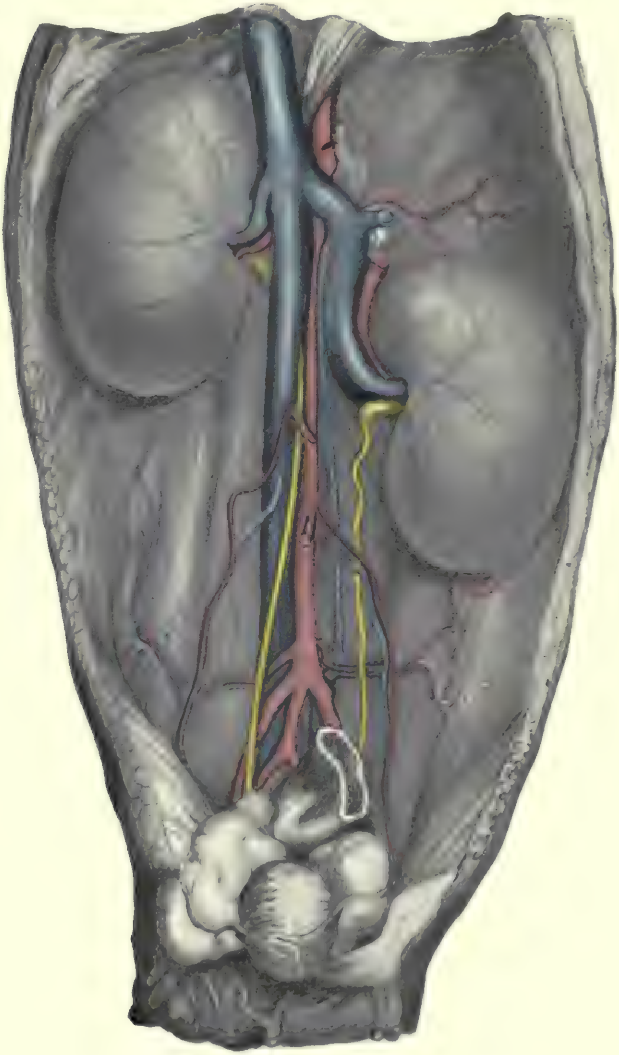

SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
URETER
RIGHT POSTCARDINAL
LEFT SUPRACARDINAL
URETER

15

PLATE XI

EXPLANATION OF FIGURE

16 Adult cat (Darrach Series), *Type* AC. Persistence of right posterior cardinal and left supracardinal veins.

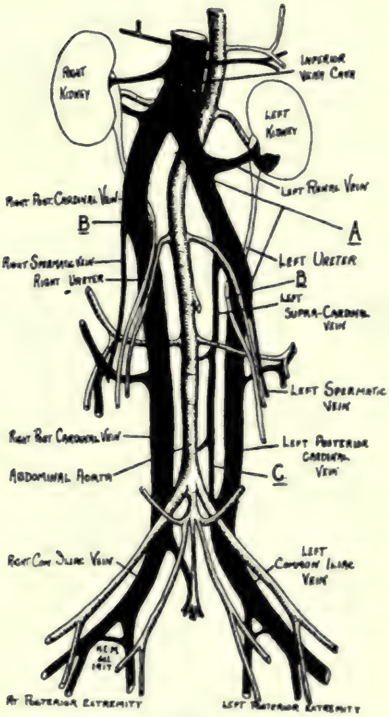


16

PLATE XII

EXPLANATION OF FIGURE

17 Adult cat (from Metcalf, fig. 1, '18), *Type* ACD. Persistence of right posterior cardinal, left supracardinal, and left posterior cardinal veins. Periureteric venous ring, through which ureter passes, present on left side. Legends by Metcalf.

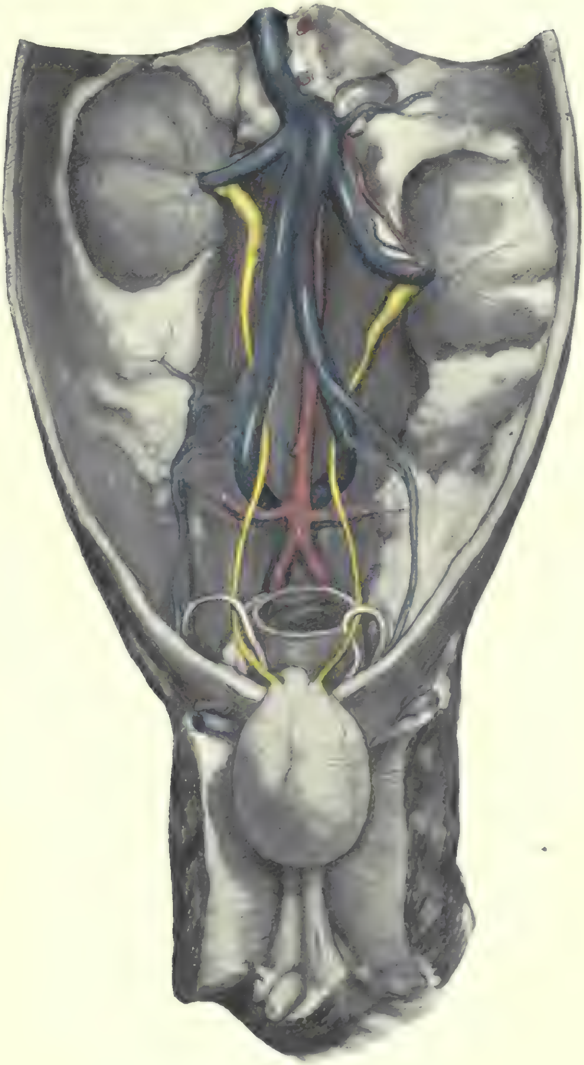

Right Kidney
Inferior Vena Cava
Left Kidney
Left Renal Vein
Right Post. Cardinal Vein
B
A
Right Spermatic Vein
Right Ureter
Left Ureter
B
Left Supra-Cardinal Vein
Left Spermatic Vein
Right Post Cardinal Vein
Left Posterior Cardinal Vein
Abdominal Aorta
C
Right Com Iliac Vein
Left Common Iliac Vein
H.E.M. del 1917
Rt Posterior Extremity
Left Posterior Extremity

17

PLATE XIII

EXPLANATION OF FIGURE

18 Adult cat (Darrach Series), *Type* AD. Persistence of right and left posterior cardinal veins. Ureters pass between aorta and caval veins.

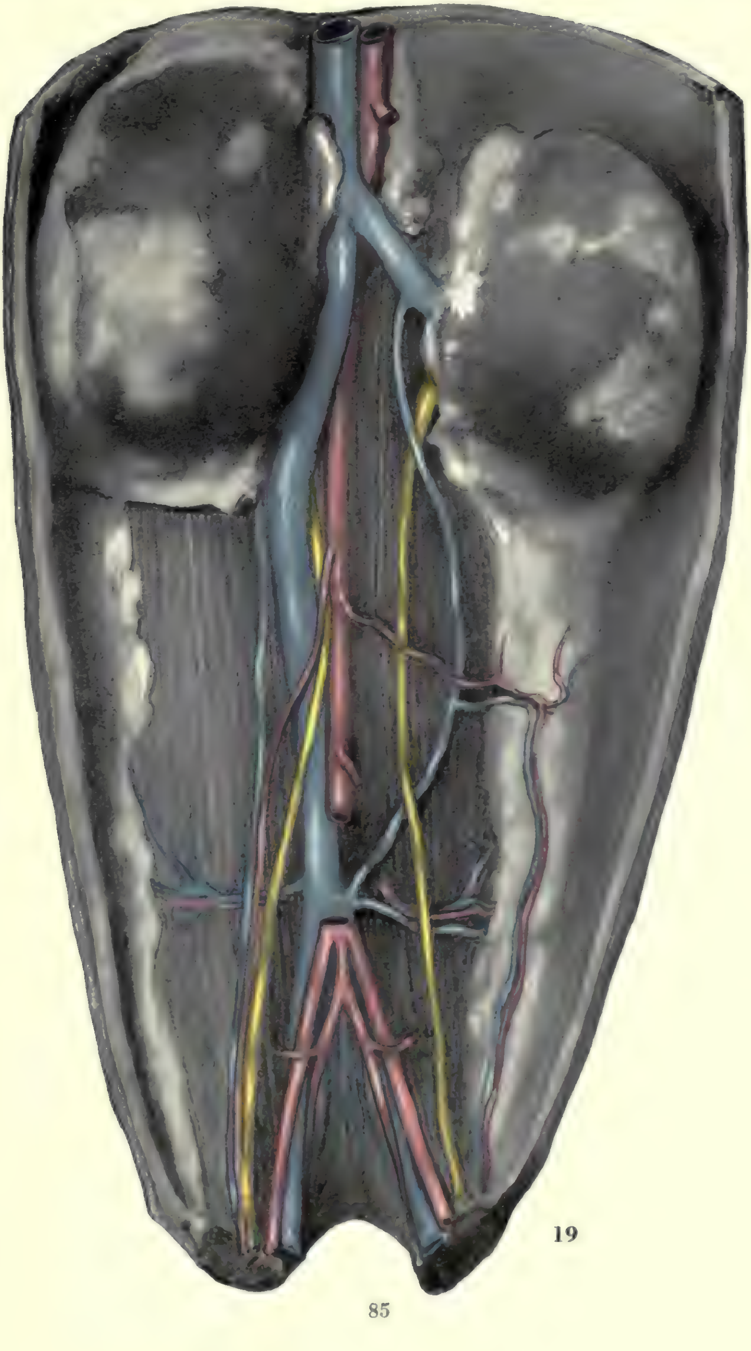


18

PLATE XIV

EXPLANATION OF FIGURE

19 Adult cat (Darrach Series), *Type* AD. Persistence of right and left posterior cardinal veins. Ureters pass between aorta and caval veins.



19

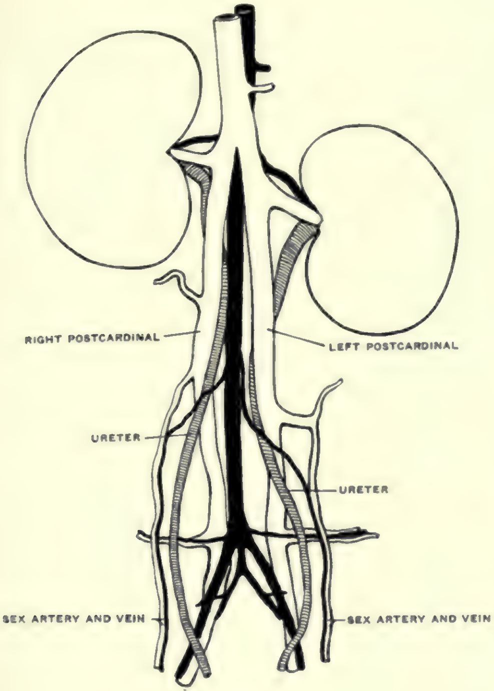
PLATE XV

EXPLANATION OF FIGURES

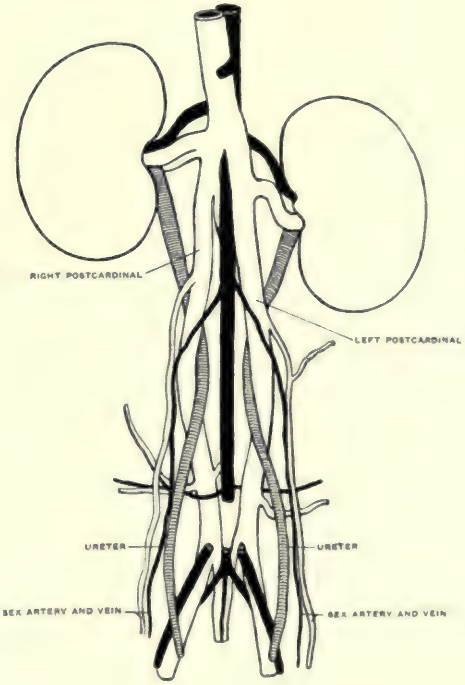
20 Adult cat (Darrach Series), *Type* AD. Persistence of right and left posterior cardinal veins. Ureters pass between aorta and caval veins.

21 Adult cat (Darrach Series), *Type* AD. Persistence of right and left posterior cardinal veins. Ureters pass between aorta and caval veins.

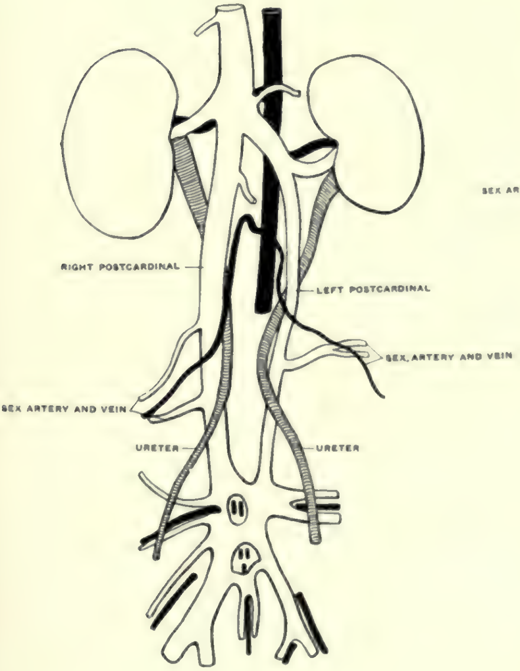
.22 Adult cat (Darrach Series), *Type* AD. Persistence of right and left posterior cardinal veins. Ureters pass between aorta and caval veins.


RIGHT POSTCARDINAL
LEFT POSTCARDINAL
URETER
URETER
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN

20


RIGHT POSTCARDINAL
LEFT POSTCARDINAL
URETER
URETER
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN

21


RIGHT POSTCARDINAL
LEFT POSTCARDINAL
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
URETER
URETER

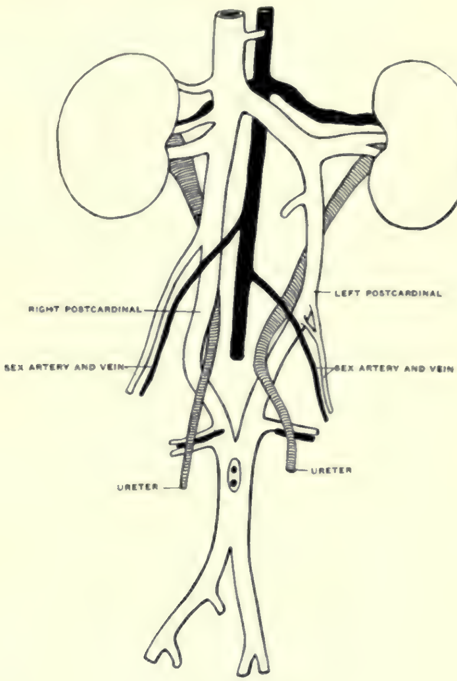
22

PLATE XVI

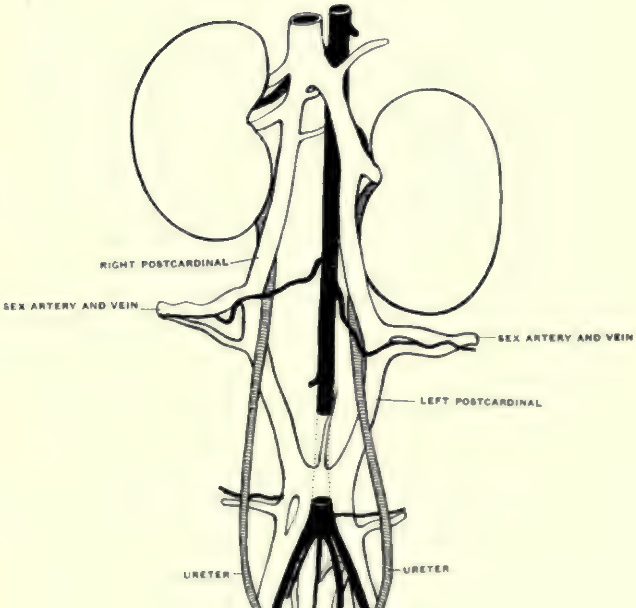
EXPLANATION OF FIGURES

23 Adult cat (Darrach Series), *Type* AD. Persistence of right and left posterior cardinal veins. Ureters pass between aorta and caval veins.

24 Adult cat (Darrach Series), *Type* AD. Persistence of right and left posterior cardinal veins. Ureters pass between aorta and caval veins.


LEFT POSTCARDINAL
RIGHT POSTCARDINAL
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
URETER
URETER

23

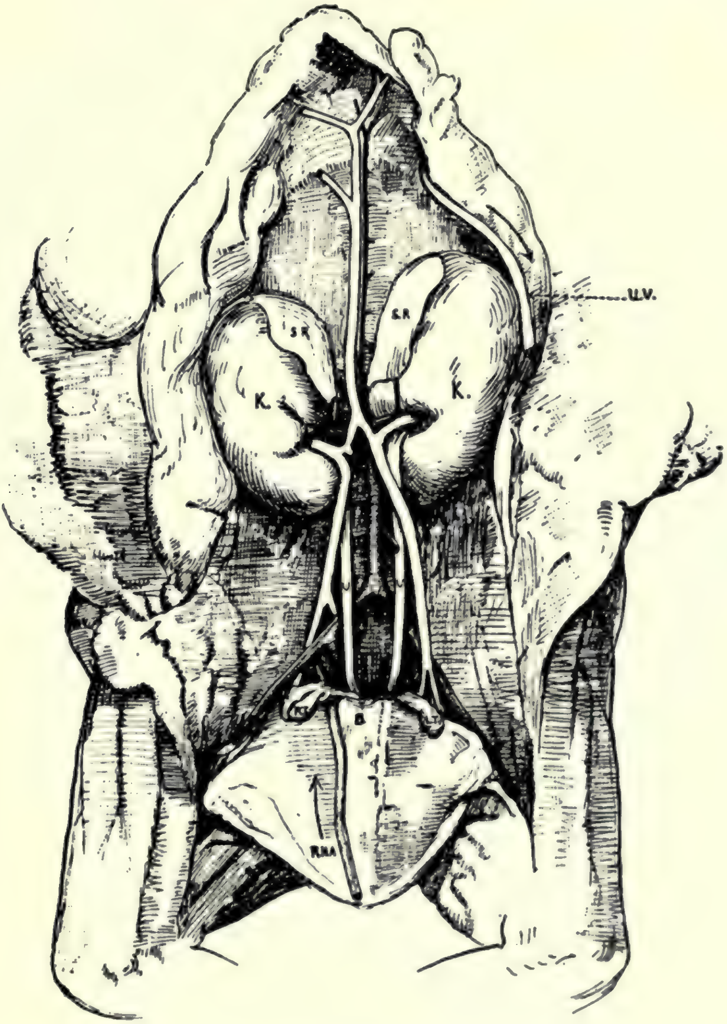

RIGHT POSTCARDINAL
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
LEFT POSTCARDINAL
URETER
URETER

24

PLATE XVII

EXPLANATION OF FIGURE

25 Man, acardiac foetus (from Gladstone, fig. 8, '12), *Type* AD. Persistence of right and left posterior cardinal veins. Ureters (*U*) pass between aorta and caval veins. Legends by Gladstone.



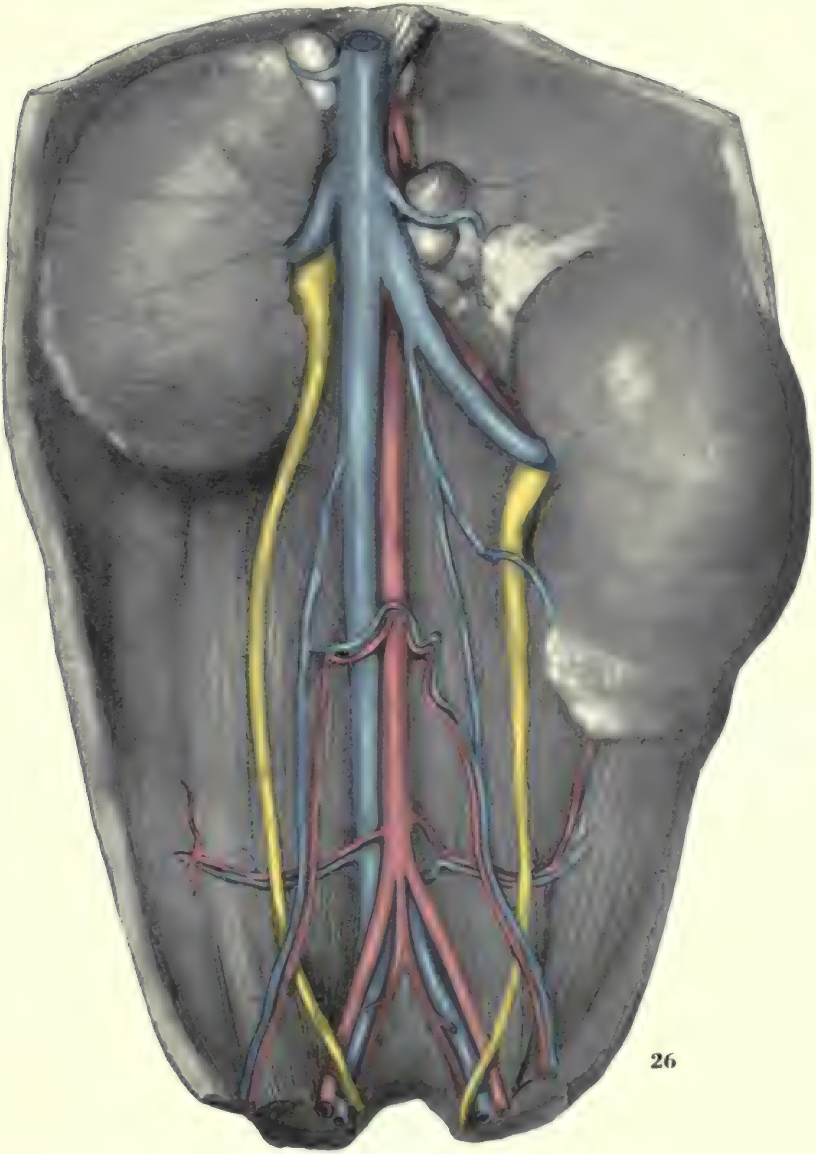
25

Drawing of the abdominal blood-vessels of an acardiac foetus, in which the ureter on each side passed behind the principal vein.

PLATE XVIII

EXPLANATION OF FIGURE

26 Adult cat (Darrach Series), *Type* B. Persistence of right supracardinal vein. Normal type of vena cava posterior (inferior) in the adult cat and in man. An atypical anastomosis present between Vv. spermaticae internae of opposite sides.

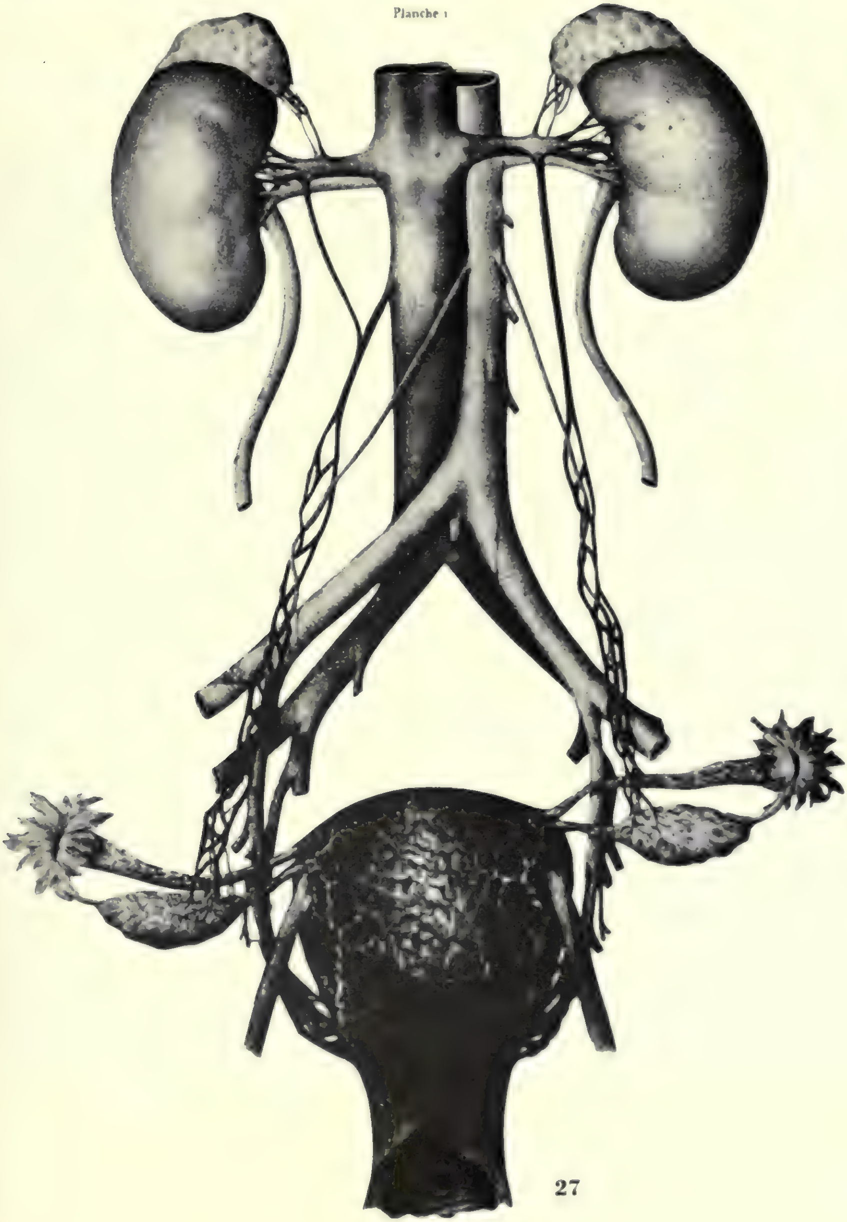


26

PLATE XIX

EXPLANATION OF FIGURE

27 Adult man (from Flourens, pl. 1, '36), *Type* B. Persistence of right supracardinal vein. Normal type of vena cava inferior in adult man. Atypical connection of V. spermatica dextra with V. renalis dextra.

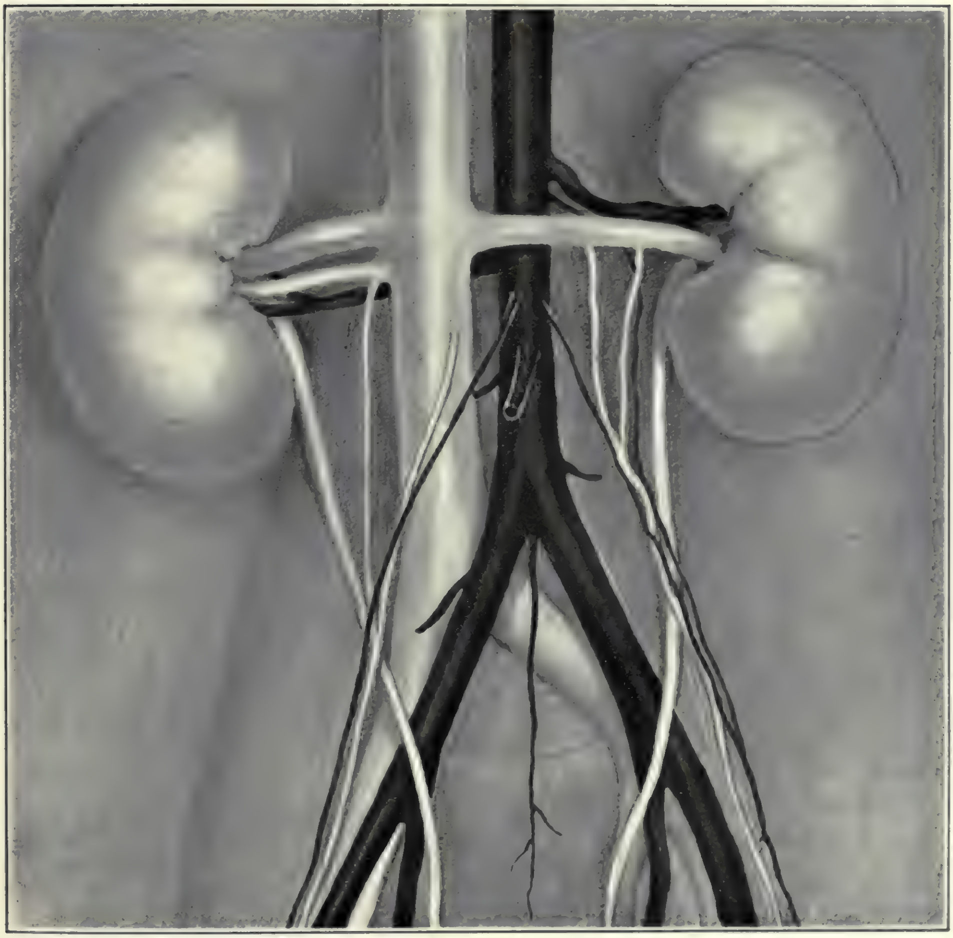


27

PLATE XX

EXPLANATION OF FIGURE

28 Adult man (Huntington Collection), *Type* B. Persistence of right supracardinal vein. Normal type of vena cava inferior in adult man. Atypical relations of vena spermatica on right and left sides.

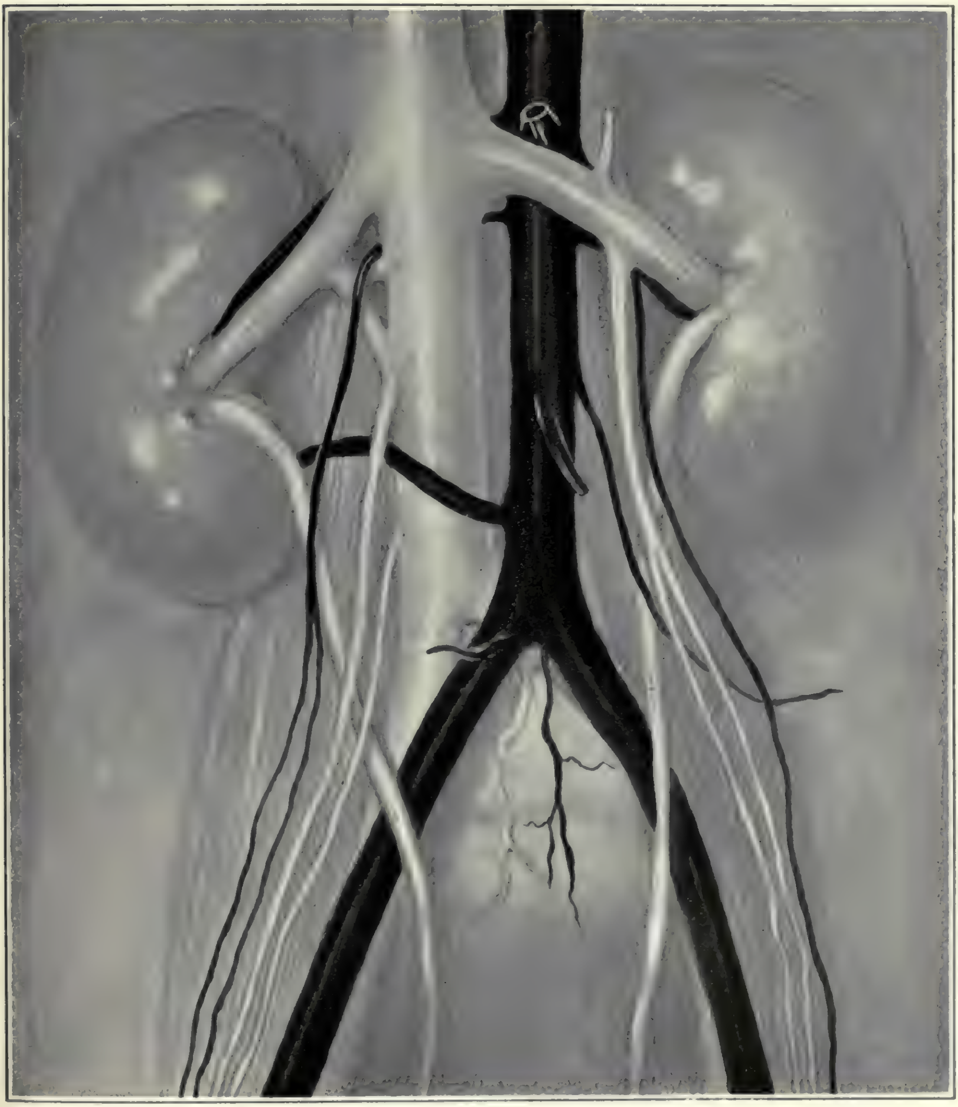


28

PLATE XXI

EXPLANATION OF FIGURE

29 Adult man (Huntington Collection), *Type* B. Persistence of right supracardinal vein. Normal type of vena cava inferior in adult man. Atypical relations of vena spermatica on right side.



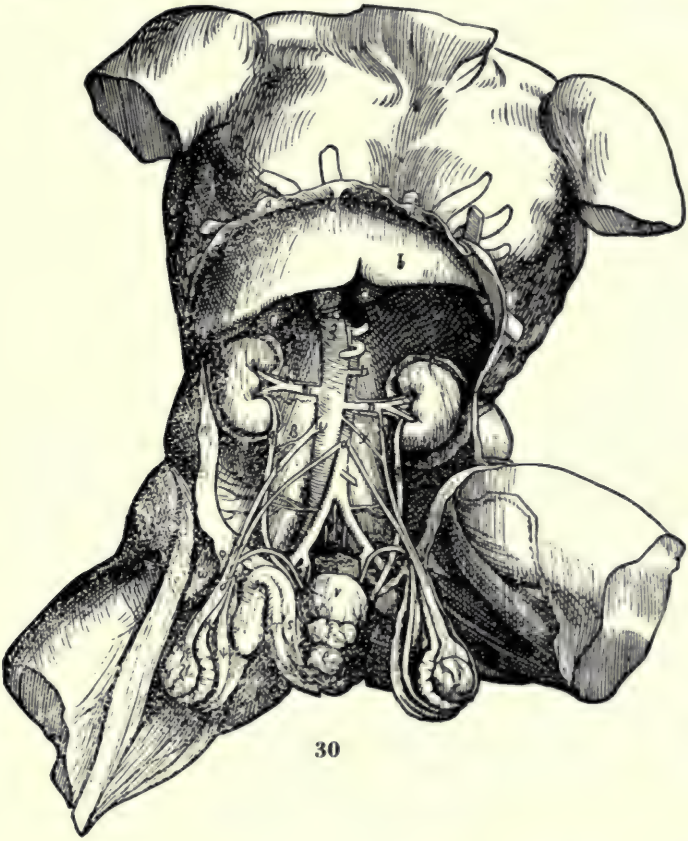
29

PLATE XXII

EXPLANATION OF FIGURE

30 Adult man (from Vesalius, 1543), *Type* B. Normal type of vena cava inferior in adult man. Atypical relations of vena spermatica sinistra.

VIGESIMASECVNDA QVINTI LIBRI FIGVRA.



30

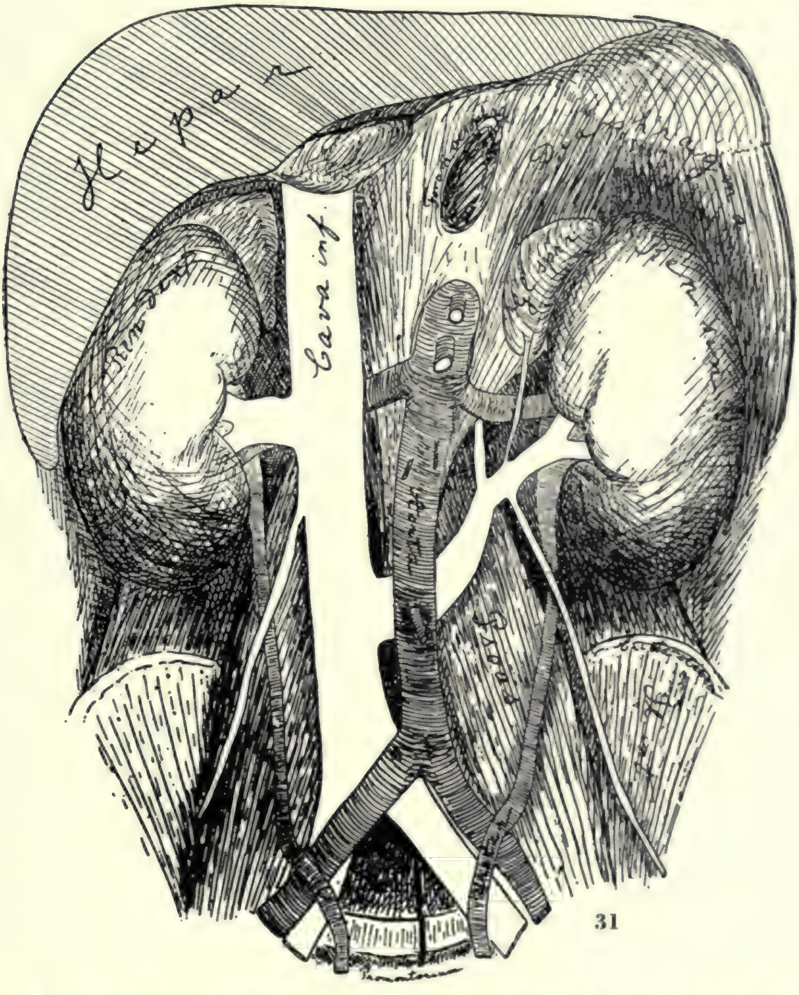
VIGE.

y *Venula à uenæ cauæ caudice pronata, ac uenæ ſeminali ſiniſtræ commixta unitáue. Quamuis enim hæc uenula rariùs occurrat, tamen quum in alijs figuris ſiniſtra uena abſque hac delineatur, illaq; hic nihil obſcuret, ipſam exprimere uiſum eſt.*

PLATE XXIII

EXPLANATION OF FIGURE

31 Adult man (from Froriep, '95), *Type* B. Persistence of right supracardinal vein. Normal type of vena cava inferior in adult man. Atypical vena renalis sinistra. Legends by Froriep.



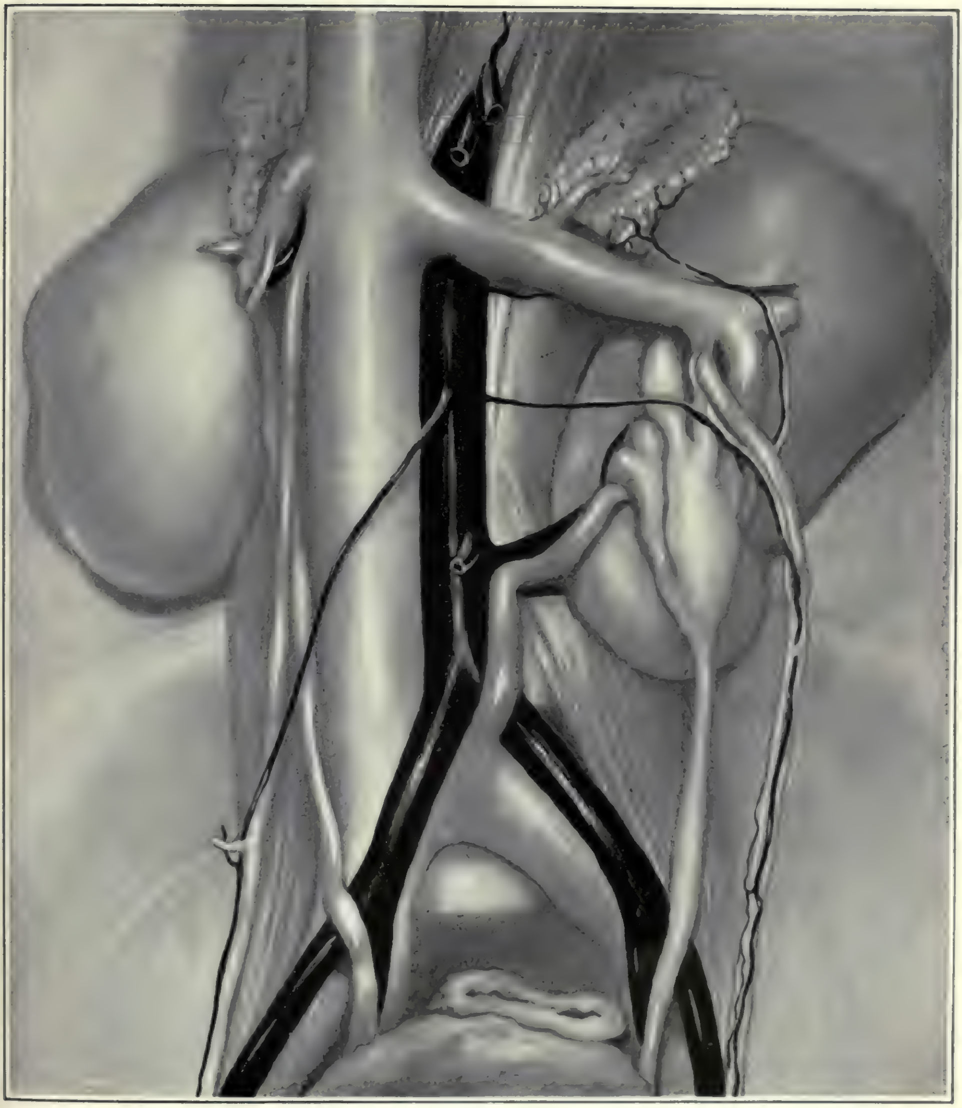
31

Fall I, nach dem Präparat gez. von August Froriep, halbe natürl. Größe. Die vordere Hälfte der Leber war durch einen frontalen Schnitt abgetragen und alle übrigen intraperitonealen Eingeweide vollständig entfernt. Die Venen sind in der Zeichnung unschraffirt gelassen, ihre Erklärung siehe im Text.

PLATE XXIV

EXPLANATION OF FIGURE

32 Adult man (Huntington Collection), *Type* B. Persistence of right supracardinal vein. Normal type of vena cava inferior in adult man. Atypical accessory vena renalis sinistra.

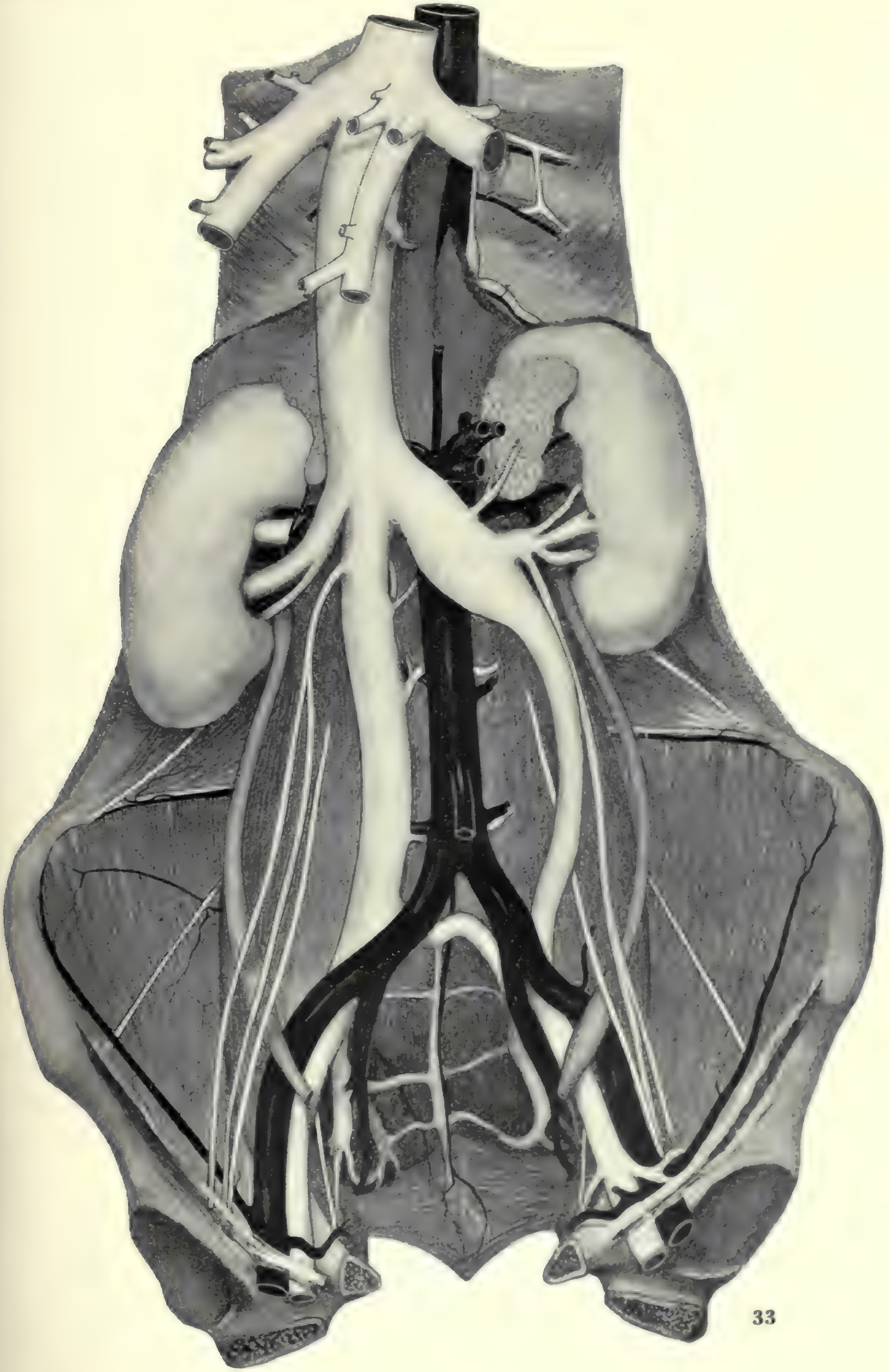


32

PLATE XXV

EXPLANATION OF FIGURE

33 Adult man (Huntington Collection), *Type* BC. Persistence of right and left supracardinal veins.

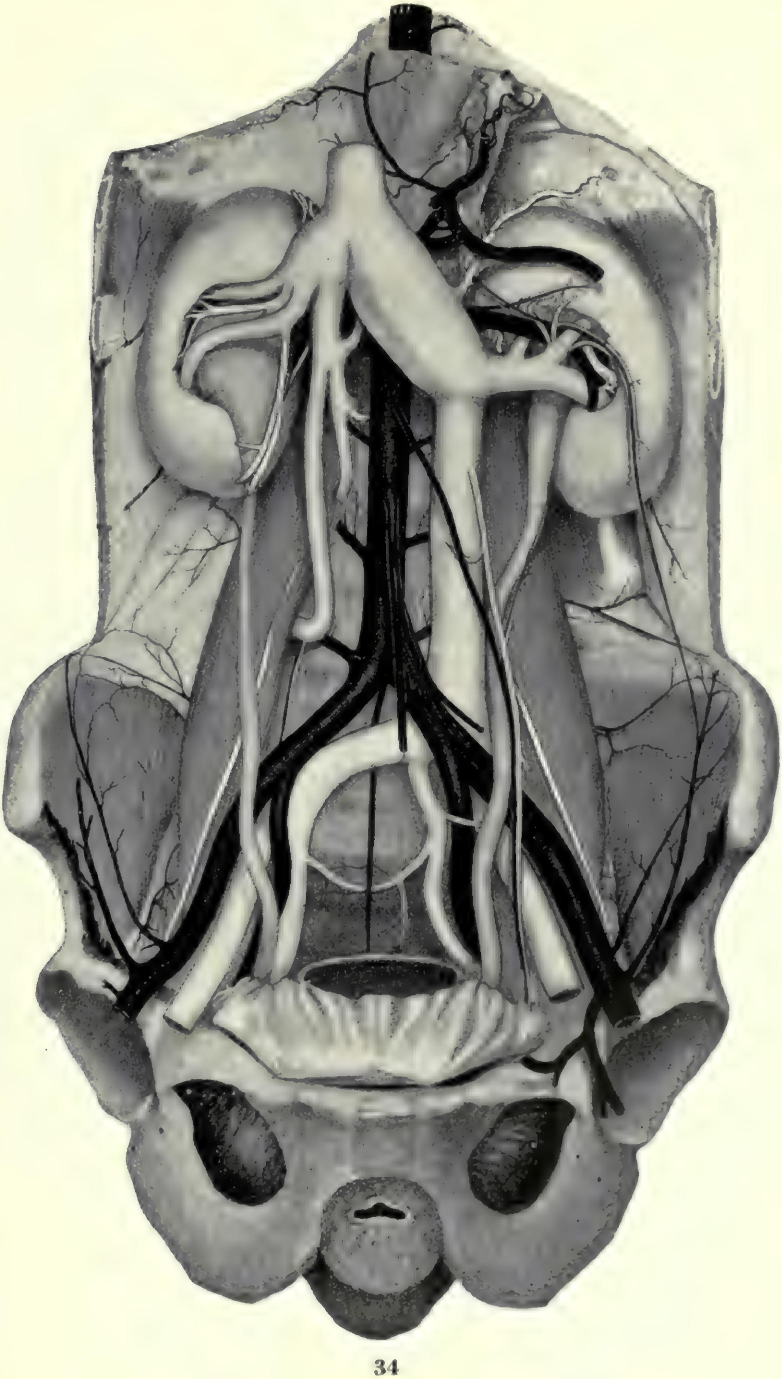


33

PLATE XXVI

EXPLANATION OF FIGURE

34 Adult man (Huntington Collection), *Type* BC. Persistence of right and left lumbar supracardinal veins. Caliber of caudal half of right cava much reduced in size.

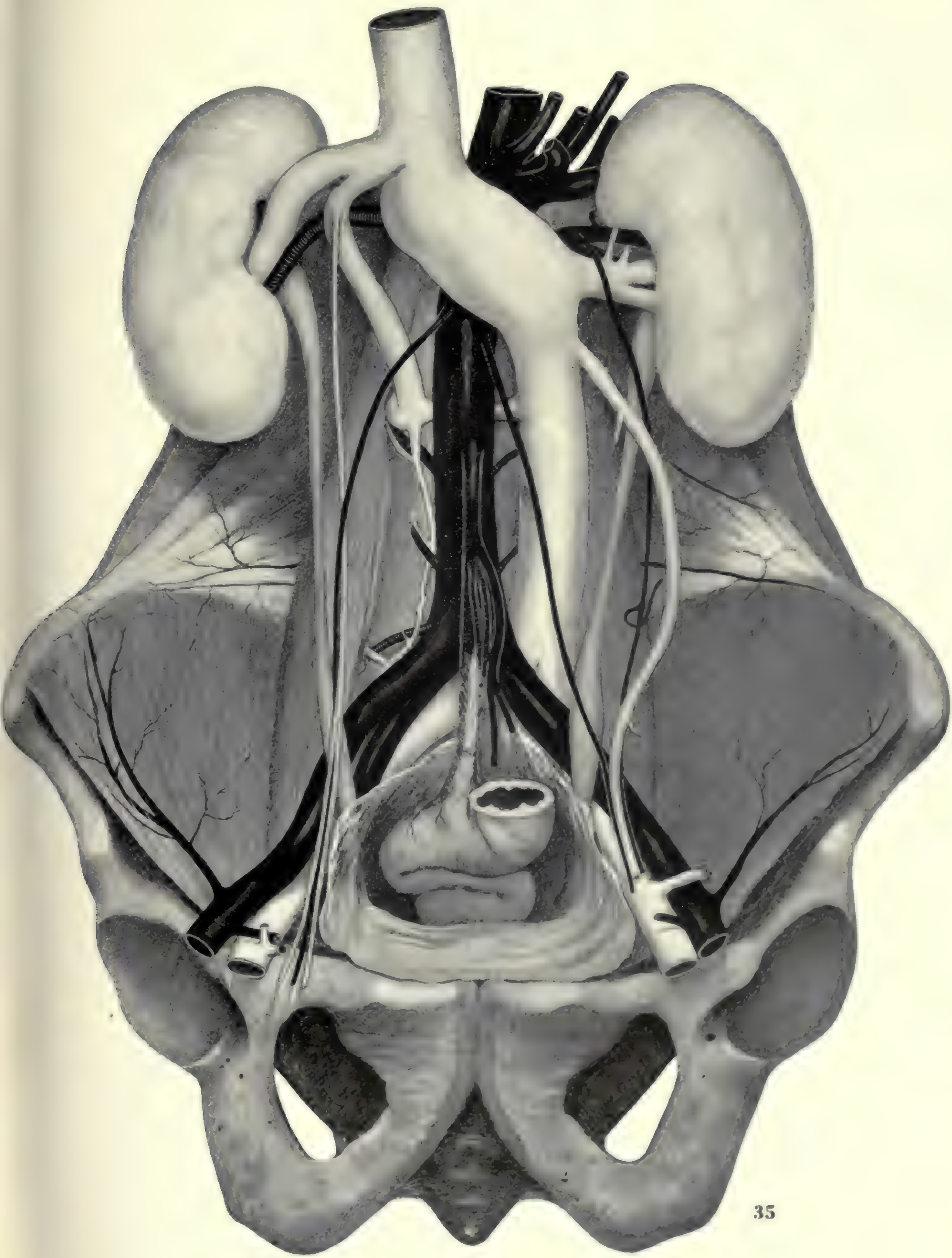


34

PLATE XXVII

EXPLANATION OF FIGURE

35 Adult man (Huntington Collection), *Type* BC. Persistence of right and left lumbar supracardinal veins. Persistence of intersupracardinal anastomosis, dorsal to aorta, between supracardinal veins of opposite sides.



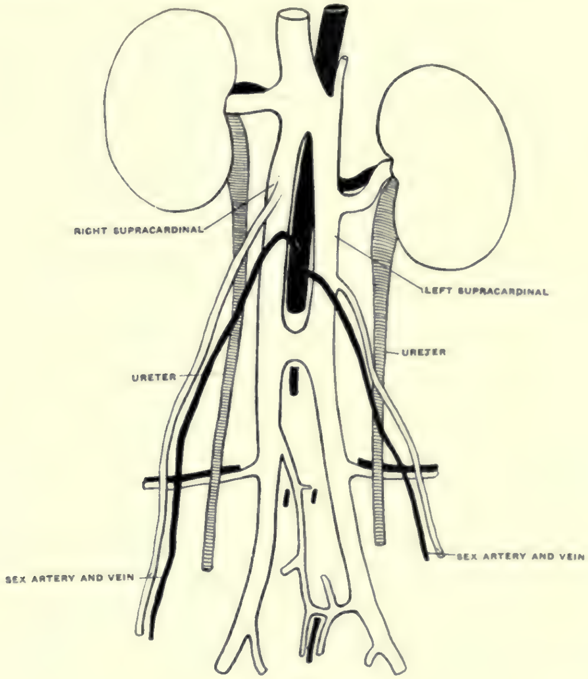
35

PLATE XXVIII

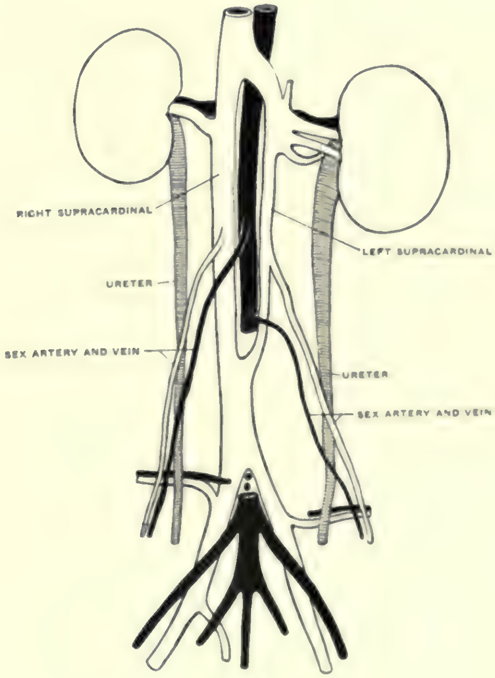
EXPLANATION OF FIGURES

36 Adult cat (Darrach Series), *Type* BC. Persistence of right and left supracardinal veins. Persistence of intersupracardinal anastomosis in midlumbar region, dorsal to aorta, between supracardinal veins of opposite sides.

37 Adult cat (Darrach Series), *Type* BC. Persistence of right supracardinal and cranial half of left lumbar supracardinal vein.


RIGHT SUPRACARDINAL
LEFT SUPRACARDINAL
URETER
URETER
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN

36


RIGHT SUPRACARDINAL
LEFT SUPRACARDINAL
URETER
SEX ARTERY AND VEIN
URETER
SEX ARTERY AND VEIN

37

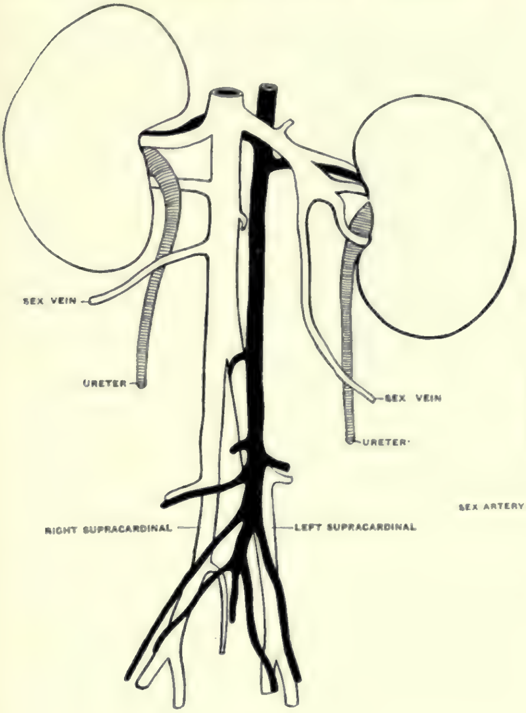
PLATE XXIX

EXPLANATION OF FIGURES

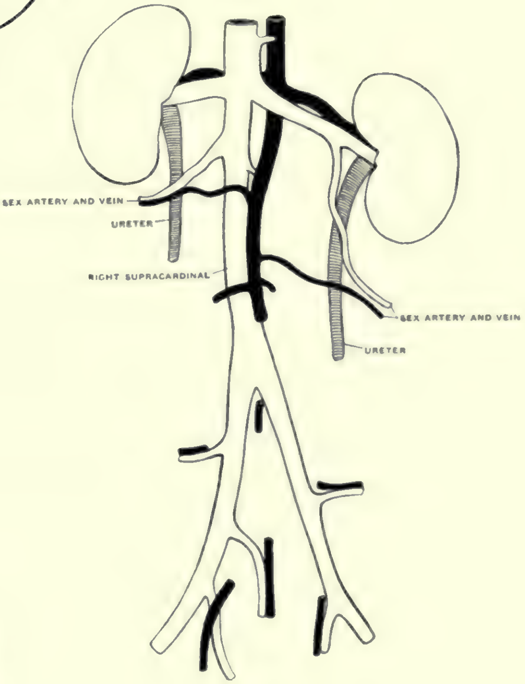
38 Adult cat (Darrach Series), *Type* BC. Persistence of right lumbar supracardinal and caudal section of left lumbar supracardinal vein.

39 Adult cat (Darrach Series), *Type* BC. Persistence of right lumbar supracardinal and caudal section of left lumbar supracardinal vein.

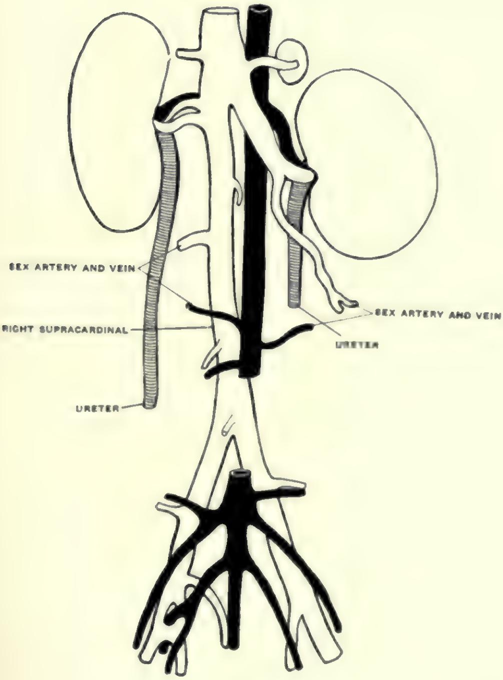
40 Adult cat (Darrach Series), *Type* BC. Persistence of right lumbar supracardinal and caudal section of left lumbar supracardinal vein.


SEX VEIN
URETER
SEX VEIN
URETER
RIGHT SUPRACARDINAL
LEFT SUPRACARDINAL

38


SEX ARTERY AND VEIN
URETER
RIGHT SUPRACARDINAL
SEX ARTERY AND VEIN
URETER

39


SEX ARTERY AND VEIN
RIGHT SUPRACARDINAL
URETER
SEX ARTERY AND VEIN
URETER

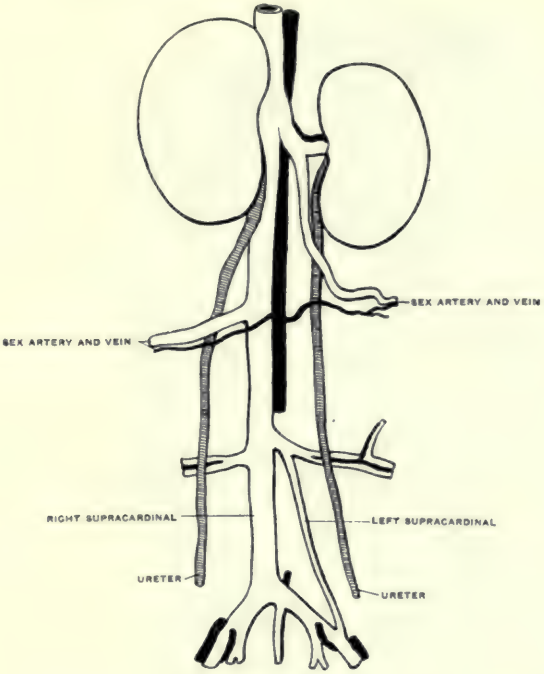
40

PLATE XXX

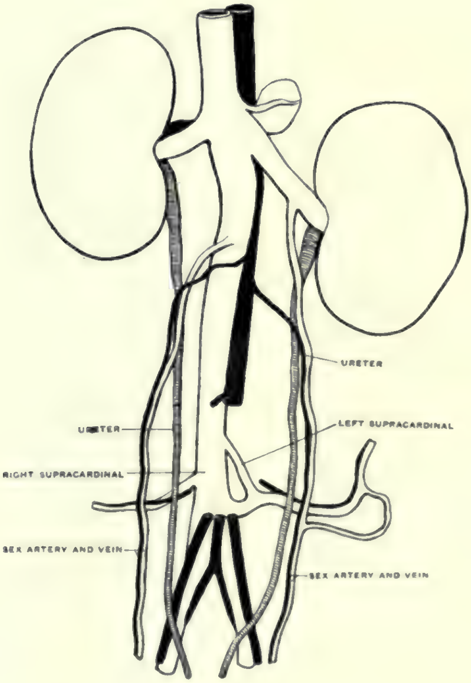
EXPLANATION OF FIGURES

41 Adult cat (Darrach Series), *Type* BC. Persistence of right lumbar supracardinal and caudal section of left lumbar supracardinal vein. Anastomosis present, dorsal to aorta, at iliac level, between iliac veins of opposite sides (left common iliac vein).

42 Adult cat (Darrach Series), *Type* BC. Persistence of right lumbar supracardinal and caudal section of left lumbar supracardinal vein. Anastomosis present, dorsal to aorta, at level of iliolumbar veins.


SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
RIGHT SUPRACARDINAL
LEFT SUPRACARDINAL
URETER
URETER

41

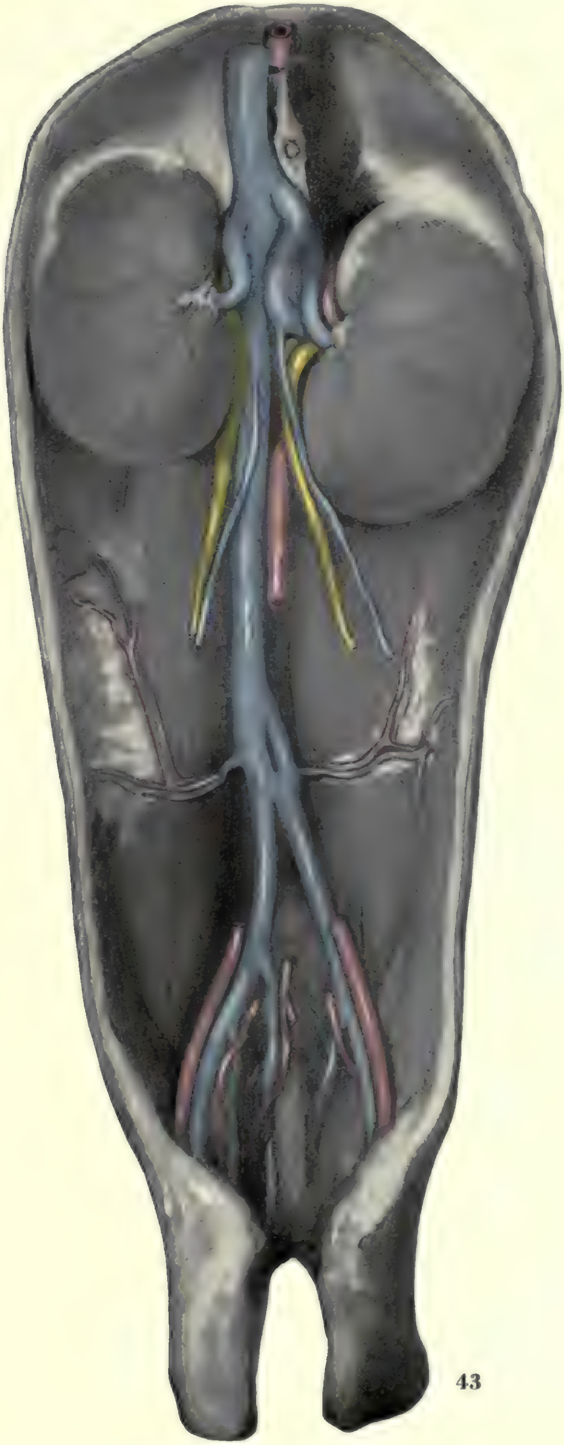

URETER
URETER
LEFT SUPRACARDINAL
RIGHT SUPRACARDINAL
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN

42

PLATE XXXI

EXPLANATION OF FIGURE

43 Adult cat (Darrach Series), *Type* BC. Persistence of right lumbar supracardinal and caudal section of left lumbar supracardinal vein. Anastomosis present, dorsal to aorta, at level of iliolumbar veins.



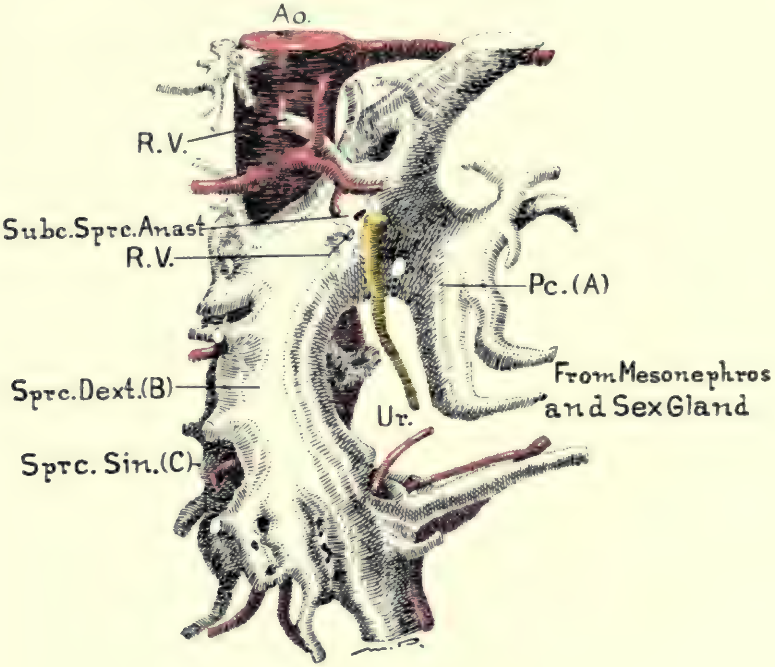
43

PLATE XXXII

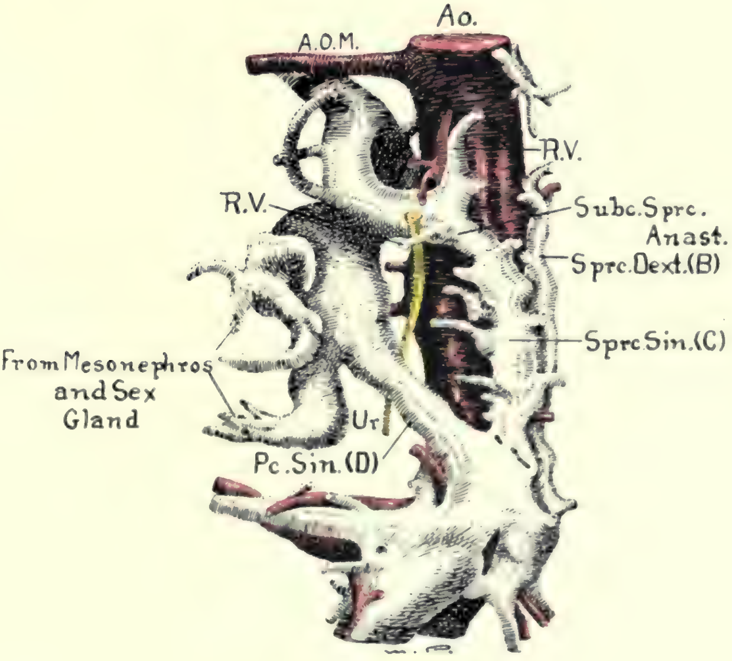
EXPLANATION OF FIGURES

44 Reconstruction (after Born) of veins in the lumbar region of a 17-mm. cat embryo. Lateral aspect, *right* side. Princeton Embryological Collection, no. 36.

45 Reconstruction (after Born) of veins in the lumbar region of a 17-mm. cat embryo. Lateral aspect, *left* side. Periureteric venous ring, through which ureter passes, present on the left side. In its present transition stage, the vena cava posterior is represented by *Type* BCD (right and left supracardinal, and left posterior cardinal veins). Princeton Embryological Collection, no. 36.


Ao.
R.V.
Subc.Sprc.Anast
R.V.
Pc.(A)
From Mesonephros and Sex Gland
Sprc.Dext.(B)
Ur.
Sprc. Sin.(C)

44


Ao.
A.O.M.
R.V.
R.V.
Subc.Sprc. Anast.
Sprc.Dext.(B)
Sprc.Sin.(C)
From Mesonephros and Sex Gland
Ur.
Pc.Sin.(D)

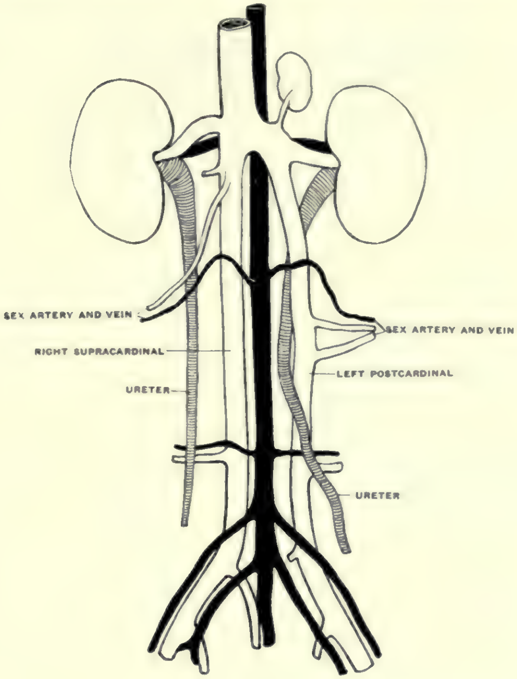
45

PLATE XXXIII

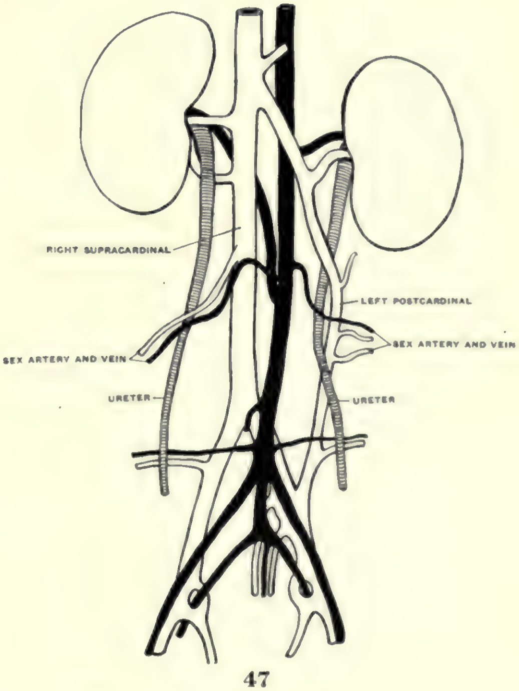
EXPLANATION OF FIGURES

46 Adult cat (Darrach Series), *Type* BD. Persistence of right supracardinal and left posterior cardinal veins.

47 Adult cat (Darrach Series), *Type* BD. Persistence of right supracardinal and left posterior cardinal veins.


SEX ARTERY AND VEIN
RIGHT SUPRACARDINAL
URETER
SEX ARTERY AND VEIN
LEFT POSTCARDINAL
URETER

46


RIGHT SUPRACARDINAL
LEFT POSTCARDINAL
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
URETER
URETER

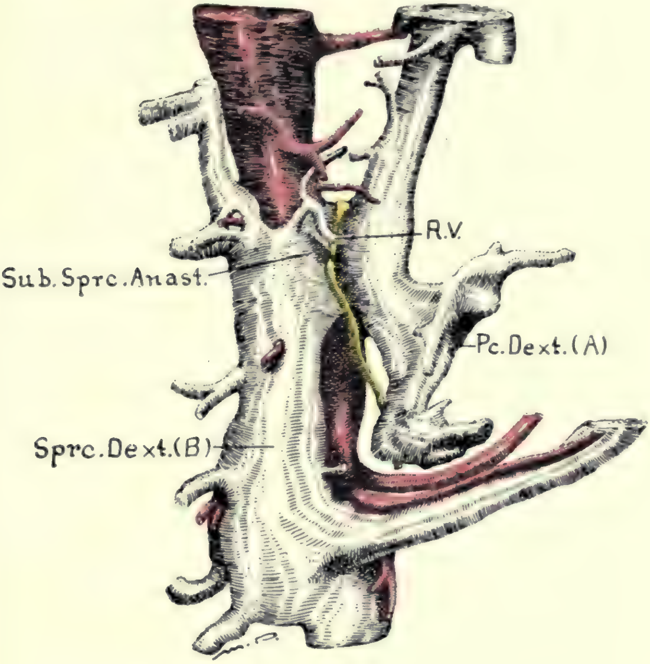
47

PLATE XXXIV

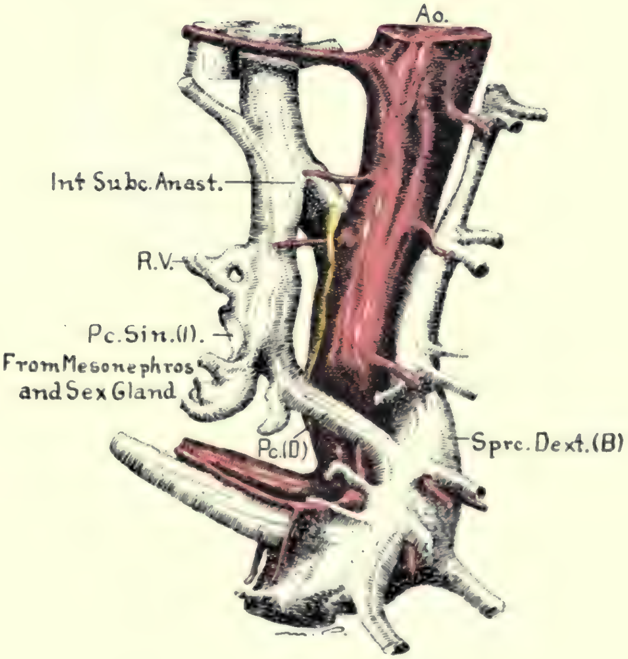
EXPLANATION OF FIGURES

48 Reconstruction (after Born) of veins in the lumbar region of a 23-mm. cat embryo. Lateral aspect, *right* side. Note presence of right side of renal collar (*Subc.Sprc.Anast.*) and fusion between right and left supracardinal veins. Coll. of P. and S. Embryological Collection, no. 569.

49 Reconstruction (after Born) of veins in the lumbar region of a 23-mm. cat embryo. Lateral aspect, *left* side. Note absence of left side of renal collar and presence of left posterior cardinal vein (*Pc.-D*). In its present transition stage, the vena cava is represented by *Type* BD (right supracardinal and left posterior cardinal veins). Coll. of P. and S. Embryological Collection, no. 569.


R.V.
Sub. Sprc. Anast.
Pc. Dext. (A)
Sprc. Dext. (B)

48

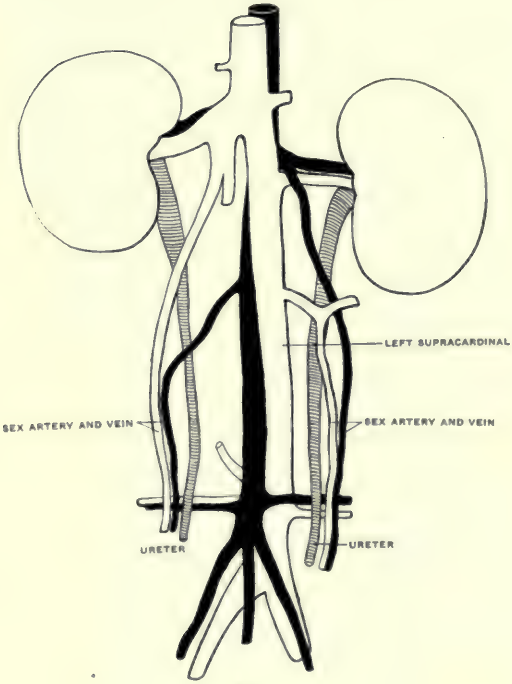

Ao.
Int Subc. Anast.
R.V.
Pc. Sin. (I).
From Mesonephros and Sex Gland
Pc. (D)
Sprc. Dext. (B)

49

PLATE XXXV

EXPLANATION OF FIGURE

50 Adult cat (Darrach Series), *Type* C. Persistence of left supracardinal vein.

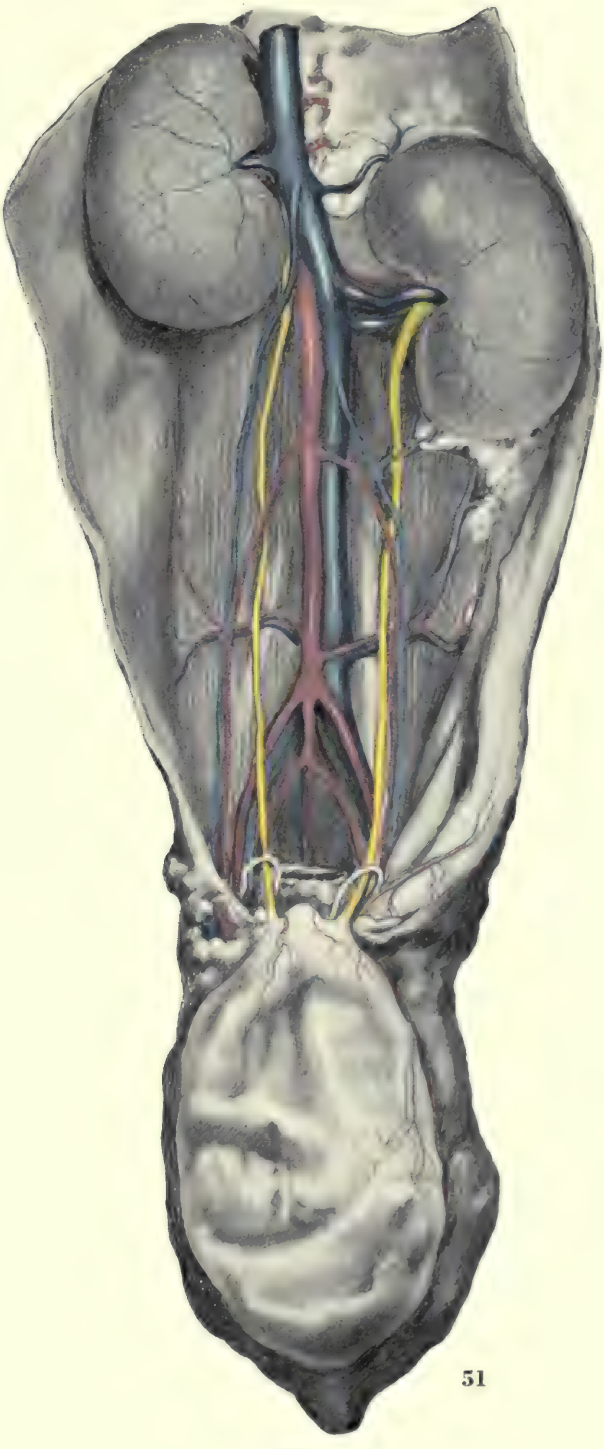

LEFT SUPRACARDINAL
SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
URETER
URETER

50

PLATE XXXVI

EXPLANATION OF FIGURE

51 Adult cat (Darrach Series), *Type* C. Persistence of left supracardinal vein.

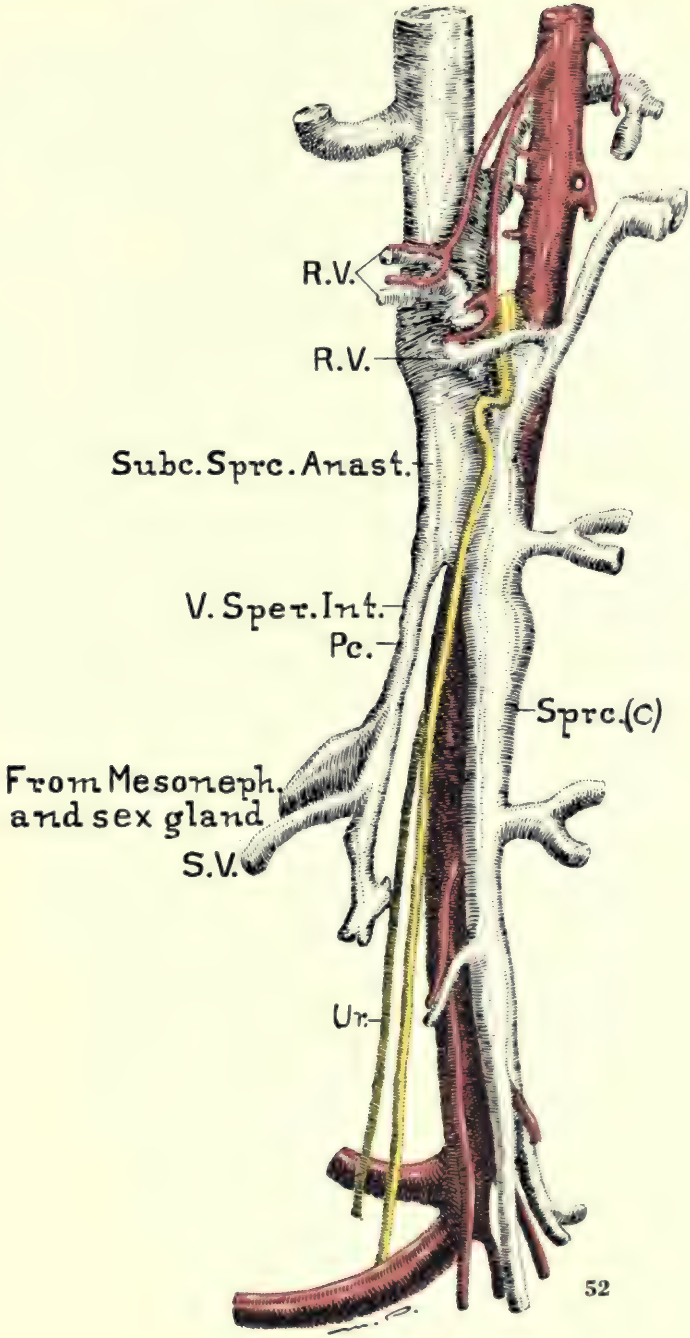


51

PLATE XXXVII

EXPLANATION OF FIGURE

52 Reconstruction (after Born) of veins in the lumbar region of a 45-mm. cat embryo. Lateral aspect, *left* side. *Type* C (left supracardinal vein). Note elongated left side of renal collar (*Subc.Sprc.Anast.*), which forms a segment of the vena cava; also, opening of V. spermatica interna (*Pc.*) into cava at caudal end of renal collar (*Subc.Sprc.Anast.*). Princeton Embryological Collection, no. 14.

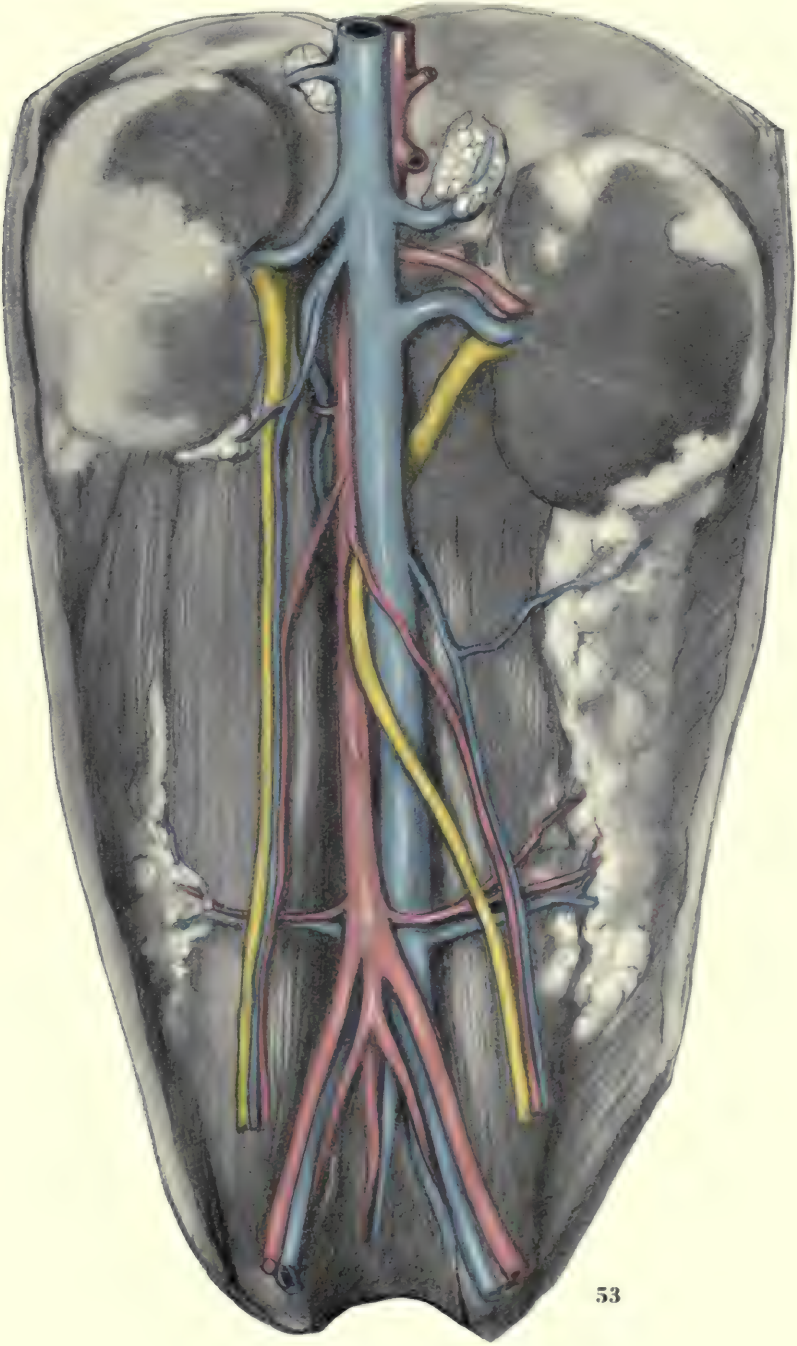

R.V.
R.V.
Subc.Sprc.Anast.
V. Sper.Int.
Pc.
Sprc.(C)
From Mesoneph. and sex gland
S.V.
Ur.

52

PLATE XXXVIII

EXPLANATION OF FIGURE

53 Adult cat (Darrach Series), *Type* D. Persistence of left posterior cardinal vein.

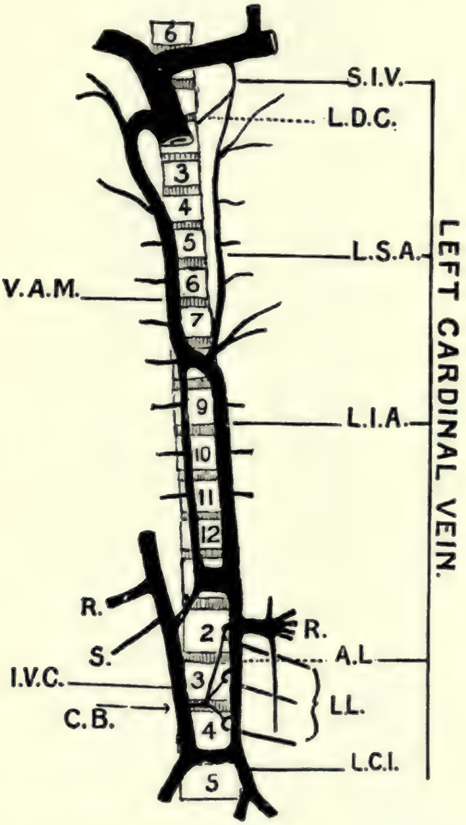


53

PLATE XXXIX

EXPLANATION OF FIGURE

54 Adult man (after Fawcett, fig. 5, '98). Persistence of embryonic supracardinal system of veins, continuous in lumbar and thoracic regions. Prerenal division of vena cava inferior also present. Legends by Fawcett.



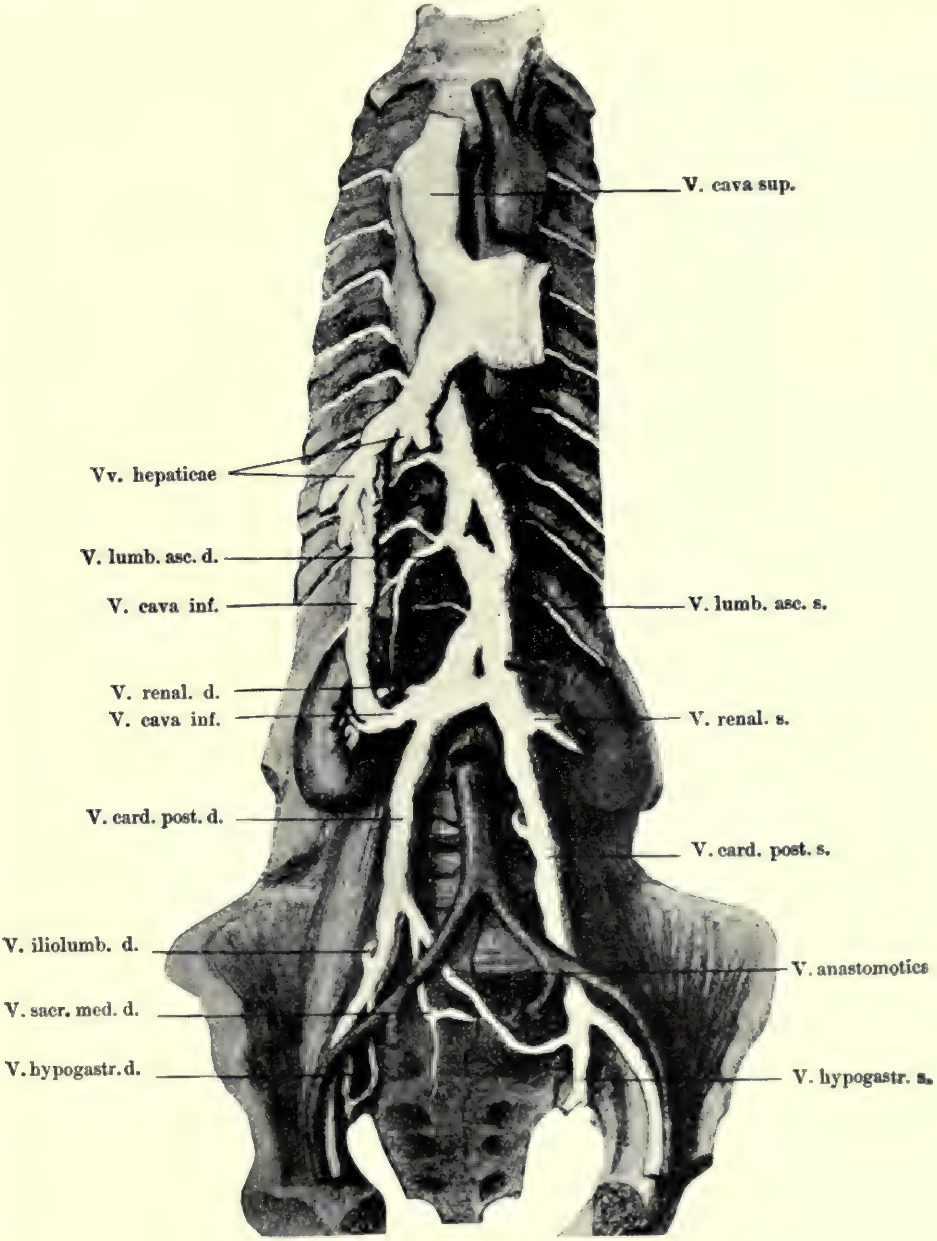
54

S.I.V., left sup. intercostal vein; *L.D.C.*, lower part of left duct of Cuvier; *L.S.A.*, left sup. azygos vein; *L.I.A.*, left inf. azygos vein; *R.R.*, right and left renal veins; *A.L.*, ascending lumbar; *L.L.*, left lumbar veins; *L.C.I.*, left common iliac; *C.B.*, common trunk uniting left lumbar veins and bringing them into communication with inf. vena cava; *I.V.C.*, inf. vena cava; *S.*, right spermatic artery; *V.A.M.*, vena azygos major.

PLATE XL

EXPLANATION OF FIGURE

55 Adult man (after Lauber, fig. 1, '01). Persistence of embryonic supracardinal system of veins, continuous in lumbar and thoracic regions. Prerenal division of vena cava inferior also present. Legends by Lauber.

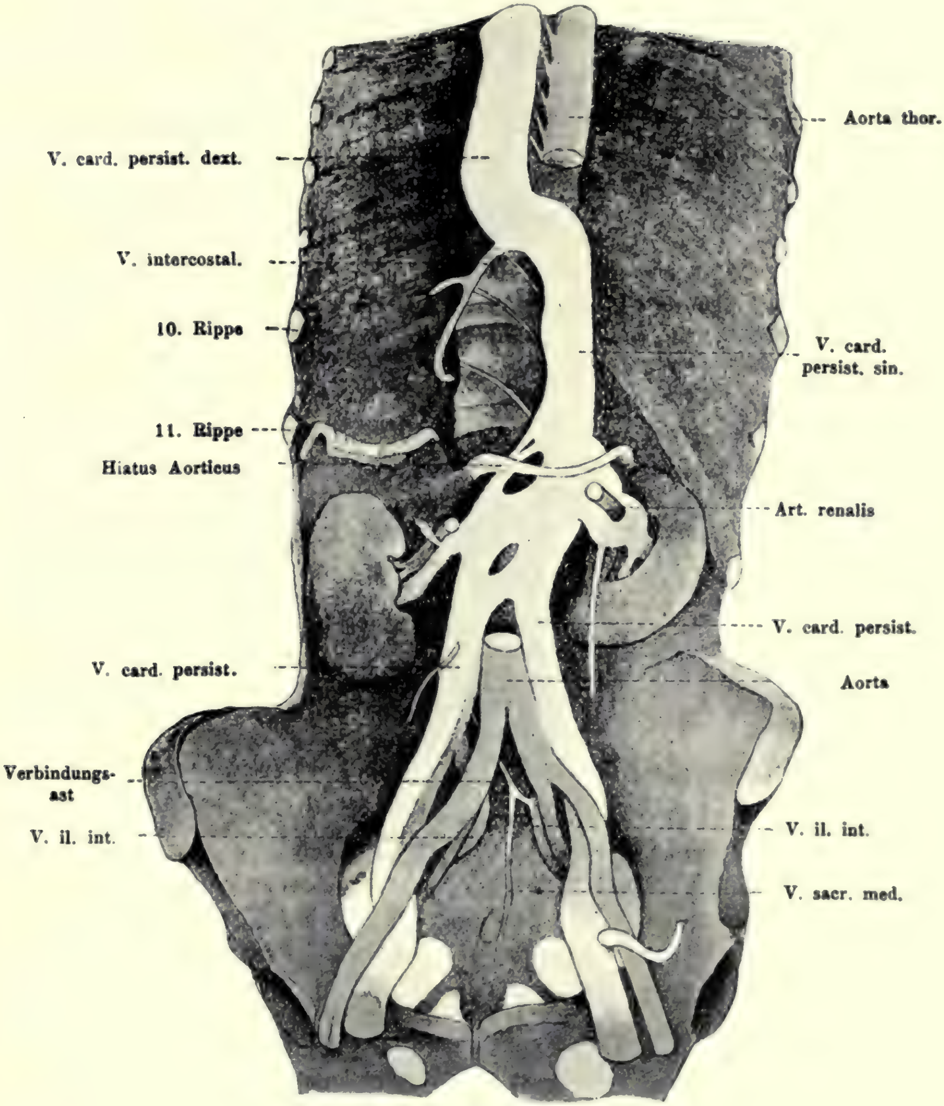

V. cava sup.
Vv. hepaticae
V. lumb. asc. d.
V. cava inf.
V. lumb. asc. s.
V. renal. d.
V. cava inf.
V. renal. s.
V. card. post. d.
V. card. post. s.
V. iliolumb. d.
V. anastomotica
V. sacr. med. d.
V. hypogastr. d.
V. hypogastr. s.

55

PLATE XLI

EXPLANATION OF FIGURE

56 Adult man (after Kollmann, fig. 3, '93). Persistence of embryonic supracardinal system of veins, continuous in lumbar and thoracic regions. Prerenal division of vena cava inferior *absent*. Legends by Kollmann.

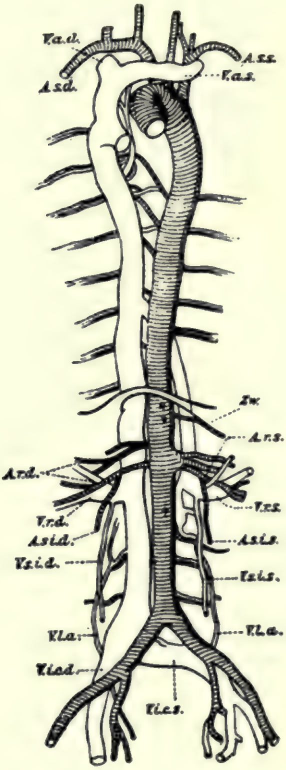

Aorta thor.
V. card. persist. dext.
V. intercostal.
10. Rippe
V. card. persist. sin.
11. Rippe
Hiatus Aorticus
Art. renalis
V. card. persist.
V. card. persist.
Aorta
Verbindungs-ast
V. il. int.
V. il. int.
V. sacr. med.

56

PLATE XLII

EXPLANATION OF FIGURE

57 Adult man (after Hochstetter, fig. 14, '93). Persistence of embryonic supracardinal system of veins (right side), continuous in lumbar and thoracic regions. Prerenal division of vena cava inferior *absent*. Legends by Hochstetter.

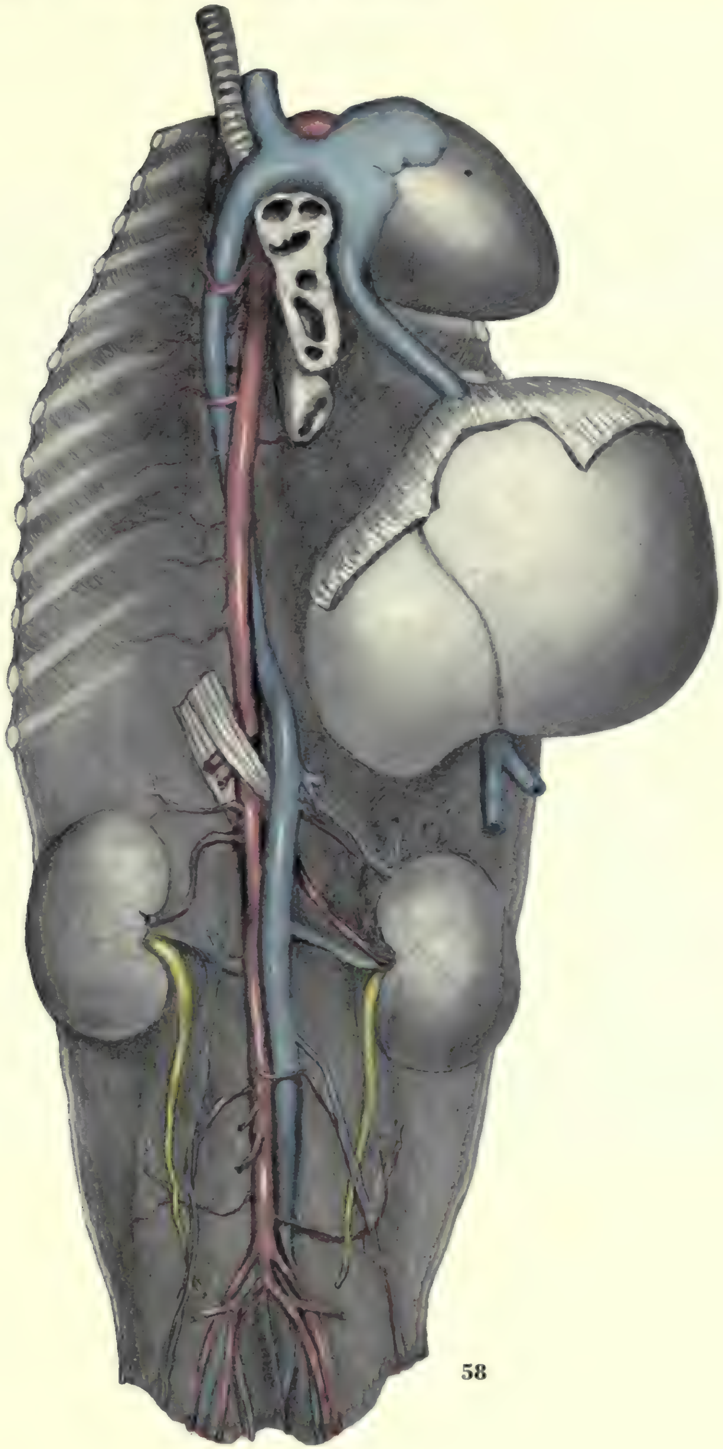

V.a.d.
A.s.s.
V.a.s.
A.s.d.
Zw.
A.r.s.
A.r.d.
V.r.s.
V.r.d.
A.s.i.d.
A.s.i.s.
V.s.i.d.
V.s.i.s.
V.l.a.
V.l.a.
V.i.c.d.
V.i.c.s.

57

PLATE XLIII

EXPLANATION OF FIGURE

58 Adult cat (Princeton Morphological Museum, no. 1040). Persistence of embryonic supracardinal system of veins, continuous in lumbar and thoracic regions. Prerenal division of vena cava posterior *absent.*

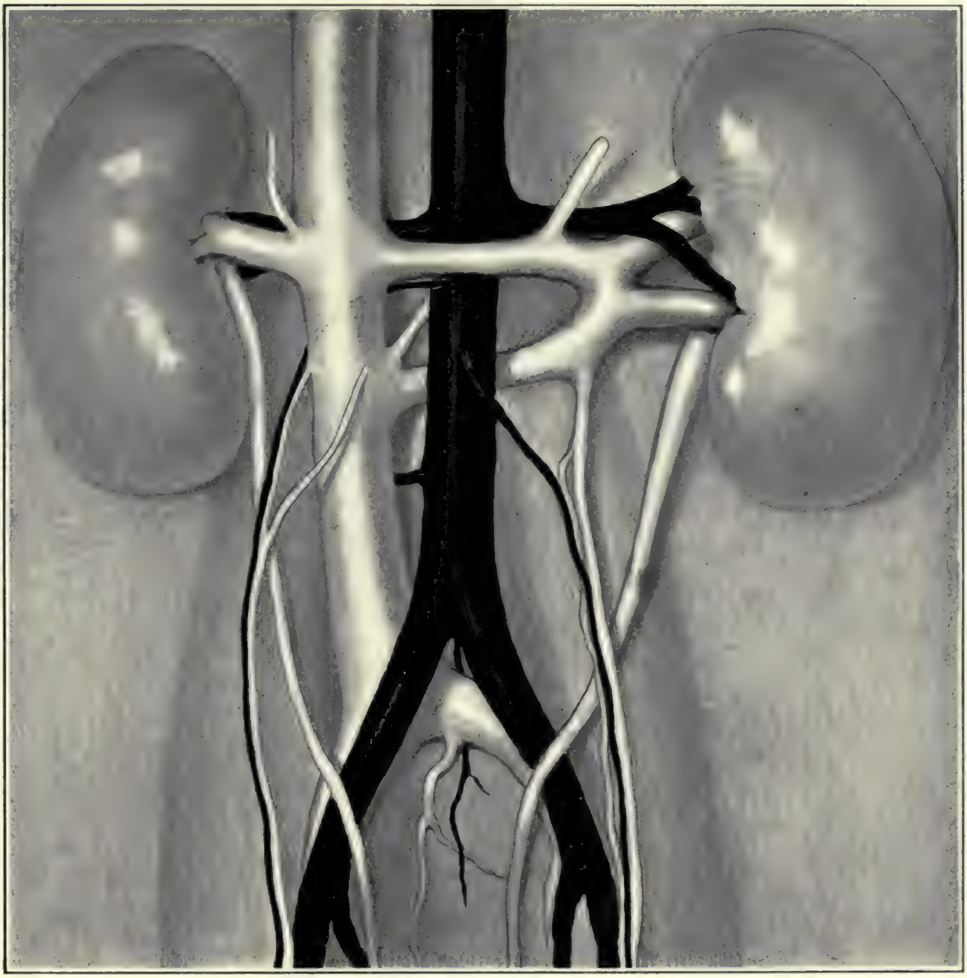


58

PLATE XLIV

EXPLANATION OF FIGURE

59 Adult man (Huntington Collection). Persistence of renal collar.



59

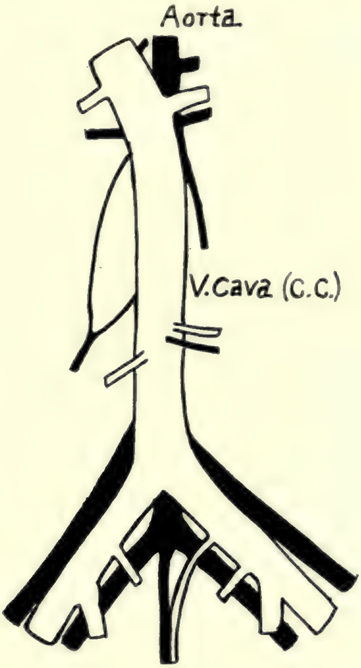
PLATE XLV

EXPLANATION OF FIGURES

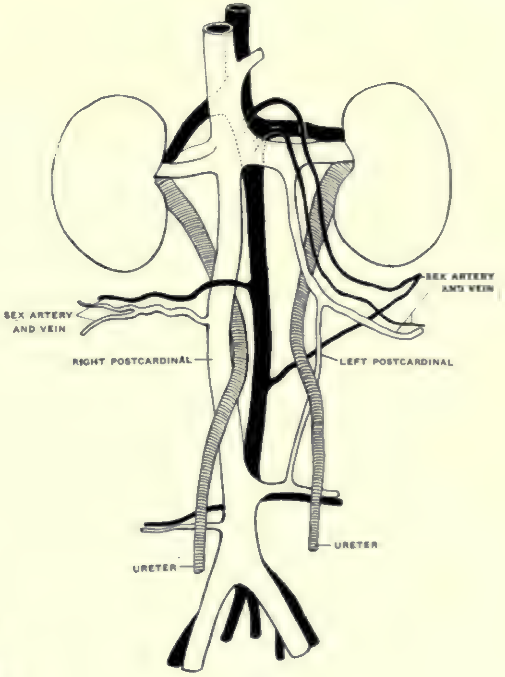
60 Marsupial Type of vena cava posterior. Vena cava posterior of Petrogale (spec.?). After McClure, figure VI, '03.

61 Adult cat (Darrach Series). Persistence of cardinal collateral channel (*C.C.*, fig. 1), in conjunction with right and left posterior cardinal veins. A combination of *Type* AD and the *Marsupial Type* of vena cava.

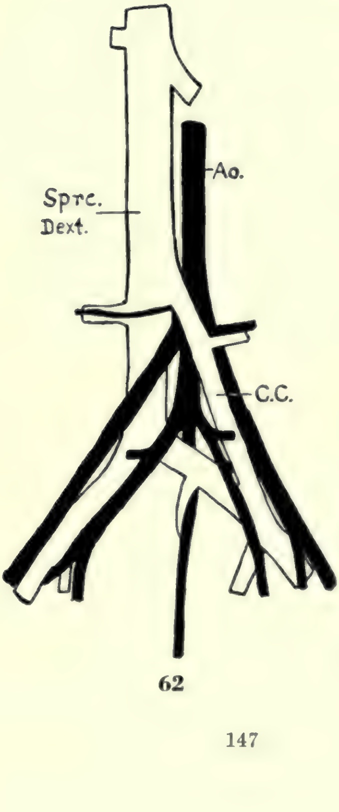
62 Adult cat (after McClure, fig. 4, '00). Persistence of cardinal collateral channel (*C.C.*) and right supracardinal vein (*Sprc.Dext.*, fig. 1). Princeton Morphological Museum, no. 603.


Aorta
V.cava (C.C.)

60


SEX ARTERY AND VEIN
SEX ARTERY AND VEIN
RIGHT POSTCARDINAL
LEFT POSTCARDINAL
URETER
URETER

61

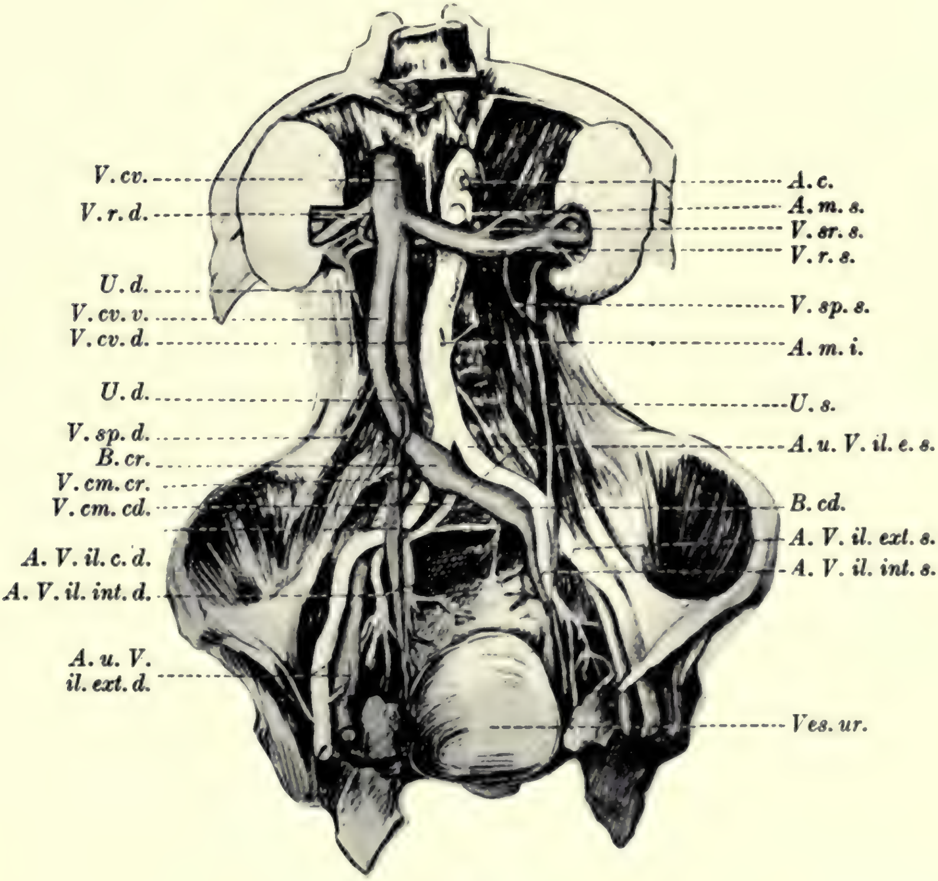

Ao.
Sprc. Dext.
C.C.

62

PLATE XLVI

EXPLANATION OF FIGURE

63 Adult man (after Wicke, Abb. 1, '27). Persistence of cardinal collateral channel (*C.C.* in fig. 1), in conjunction with right posterior cardinal and right supracardinal veins. Periureteric and circumumbilical venous rings present on right side. Legends by Wicke.


V. cv.
V. r. d.
U. d.
V. cv. v.
V. cv. d.
U. d.
V. sp. d.
B. cr.
V. cm. cr.
V. cm. cd.
A. V. il. c. d.
A. V. il. int. d.
A. u. V. il. ext. d.
A. c.
A. m. s.
V. sr. s.
V. r. s.
V. sp. s.
A. m. i.
U. s.
A. u. V. il. e. s.
B. cd.
A. V. il. ext. s.
A. V. il. int. s.
Ves. ur.

63

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